EXPLOITATION OF INFRARED IMAGING IN MEDICINE

31 January 2001

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13 ABSTRACT *(Maximum 200 words)*

This is the final report for Contract DAAG55-98-C-0035 entitled "Exploitation of Infrared Imaging in Medicine". It was initiated in 1998 as a two year project with funding from OSD, DARPA and ARO and monitored by ARO. This effort was a follow-on contract to a previous work and its objective was to generate impetus for the acceptance of infrared imaging as a valid, viable, highly successful, low-cost diagnostic and screening modality in both military and non-military medicine. The specific tasks covering this work were as follows: (a) continue to be a focal point for the medical IR technology and its exposure; keep abreast of all new developments in order to disseminate these to key people in healthcare, government, industry, academia, and the military for the purpose of creating research programs for the validation of this modality. (b) Develop teaming arrangements between medical centers and manufacturers to collaborate in initial clinical trials, and monitor quantification of clinical data at these academic centers. (c) Ensure that there is some standardization of methodology, which will entail provisions for training of relevant healthcare personnel. (d) Define image processing techniques required for standardization and interpretation of medical images. Review and select appropriate algorithms that can be integrated into IR systems for enhanced performance. (e) Organize and bring to completion the two special issues dedicated to medical infrared imaging of the IEEE/EMBS Magazine. This report contains the results of this effort and the recommendations for continuation of research in this area.

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FORWARD

Background: In the last two and a half years, substantial progress has been made in the determining of the benefits of IR imaging in medicine as reported in current literature, scientific conferences, and workshops. This has been aided by the latest advances in IR focal plane arrays which have led to superior performance cameras with the increased sensitivity and specificity required by medical users in both military and non-military medicine. Under a previous ARO effort entitled "Medical Applications of IR Focal Plane Arrays" (Contract No. DAAH04-94-C-0020), there has also been marked progress in identifying potential applications for the cost effective use of infrared imaging in medical screening, diagnosis, and therapy.

Several major areas of use were identified through in-depth review of recent literature, contact with leading medical centers, clinicians, and universities. Specifically, these are neurology, vascular disorders, arthritis and rheumatism, pain management and control, surgery,oncological and breast cancer, tissue viability, dermatological disorders, and monitoring the efficacity of drug therapy. Recently reported additional areas are dental and ophthalmology. The first six applications currently are being used clinically, and the latter six are in the research stage. It has been ascertained that the clinical areas most likely to lead in medical infrared imaging are as follows:

- Oncology (breast, skin, etc.)
- Neurology (pain management and control)
- Vascular Disorders (diabetes, etc.)
- Surgery
- Soft tissue and skin injury.
- Arthritis and rheumatological diseases
- Therapeutic monitoring (drugs and treatment)
- Combat Casualty Care (tissue viability, burns, etc.)
- Telemedicine

A unique benefit of infrared imaging is its ability to detect and characterize pathophysiological abnormalities (e.g. functional imaging) not readily identified by other means, such as X-Rays, CAT, and Ultrasonic imaging, which provide structural information. The latest enhancements in MRI systems do provide capability for both structural and functional imaging, but at a far higher cost than IR. Moreover, these modalities are not "first-line" clinical procedures.

The impact of the above findings and developments form the basis for the continued exploitation of infrared imaging in medicine and establish its potential value to the medical field. It further enhances the renewed interest in this modality, which provides a non-invasive, non-ionizing, diagnostic and therapeutic form of imaging at a very reasonable cost. It has already generated new initiatives in DOD, industry, and universities.

In 1994 the topic of infrared imaging was introduced by Advanced Concepts Analysis, Inc., to the IEEE Engineering in Medicine and Biology

Society (EMBS) for inclusion in their International Conferences and it was adopted by them as an emerging technology. This sparked the original interest in the scientific, medical and academic communities which has steadily increased and has allowed this modality to establish itself today at these conferences as a part of the "Medical Imaging Discipline' along with MRI, CAT, X-RAY, etc. IR imaging in medicine has been presented at seven of these conferences from 1994 to present.

The IEEE forum also provides a perfect setting for a yearly informal workshop; this was introduced in 1994. The purpose of these is to stimulate colloquiums and exchange of ideas between international and national scientists, academia, and industry, who attend the conference. This resulted in serious discussions and ideas of collaboration between them. Even more importantly, it further exposed in a direct manner the importance of developing the use of infrared in medicine.

The interest has been generated to the extent of several university medical centers now being willing to undertake clinical research in this field. Efforts are being expended to start collaboration between IR camera manufacturers and these centers in order to supply them with the systems required to carry out preliminary investigations. Successful results will stimulate demand for infrared cameras. This is very critical because it will form the basis for proceeding to the quantification of data stage by leading medical centers. Quantification is essential in order to establish the efficacy of this modality and convince the medical field of its value.

Primary Anticipated Results: The proposed twenty-four month effort was designed to become the impetus for the acceptance of IR imaging as a valid, viable and useful diagnostic and screening tool in medicine. In order to accomplish this, the initial research by interested academic medical centers had to implement quantification of clinical data, and publish the results in main stream medical journals, databases, and other scientific publications. This is an essential step for convincing physicians, hospitals, health care providers, and government of the merits of this effective, low-cost, non-invasive, non-ionizing imaging modality, which can be used alone or in a multi-modality sensor fusion environment.

The specific aim of this effort was to exploit the use of infrared technology in the military and non-military medical fields. This work took place over a two year period, which ended in November 2000. The dynamic process of continuing to develop teaming arrangements between manufacturers, medical centers, universities and government agencies for the purpose of spurring research and publication was a primary focus. Ongoing was also the effort of (a) setting standards and protocols of methodology in order to provide reproducible and reliable results and (b) putting academic centers in touch with those who have worked for many years in their chosen application of medical IR imaging. A major focus was the initiating of quantitative clinical studies at medical and research centers. Another major activity of this period was to continue to generate collaboration between academia, physicians, manufacturers and biomedical engineers.

Another initiative was to define image processing techniques required for interpretation and standardization of medical images and to assist in the transfer of DOD state-of-the-art computer technology that might be highly useful in the clinical area. The attempt was to be made to look at ATR technology and smart algorithms that could be integrated into IR camera systems in order to enhance imaging performance.

The participation in international meetings and workshops was of significant importance in order to insure standardization of systems, methodology, and training, and keep abreast of all new developments and findings. The close coordination of the outcome of the above activities with those carrying out the clinical work was of critical importance.

The completion of the work on the two special issues of the IEEE/EMBS Magazine was ongoing. This involved the solicitation of papers, forming a review board, revising manuscripts, editing, and coordinating the publication with the Chief Editor. This was toward achieving two publications of the highest quality.

Organizing the annual medical infrared imaging track and the workshops at the IEEE/EMBS International Conferences was continued. This work entailed solicitation of papers, forming of paper review committees, editing manuscripts to be published in proceedings, and raising funds through grant proposals to cover expenses of invited international speakers and the workshops.

Current Status: Substantial progress has been made in the collaborative area between manufacturers, medical centers, universities and government agencies in the area of medical infrared imaging. A significant number of research initiatives for quantification of clinical data are in progress in prestigious centers. This is evident from the papers and ongoing work which is published. Another collaborative effort led to the presentation of the potential of infrared imaging in the early detection of breast cancer to the Congress and Senate, and ultimately to the full presentation to the Congressional Women's Caucus. The preliminary investigation of image processing techniques and Automatic Target Recognition (ATR) technology for use in medical images yielded encouraging results and was then investigated in-depth under a separate effort. Detailed findings are contained in Final Report "Application of Army IR Technology to Medical IR Imagery" (Contract DAAH04-96-C-0086/TCN 97-143). The IEEE/EMBS International Conferences served as an important forum for continued and original work for scientists and physicians from all over the world. These were published in the relevant proceedings. In fact, in the Chicago World Congress 2000 conference, we also were invited to arrange two mini-symposia with six tutorial papers on medical infrared imaging, besides the usual track.

Two Special Issues dedicated to Medical Infrared Imaging of the IEEE/Engineering in Medicine and Biology Magazine were published in 1998 and 2000. These are available in open literature, including MEDLINE of the National Library of Medicine. These had a positive impact in such important places as FDA, NIH, and academia,etc.

Although this work has been very successful, it is essential to continue the

pattern that has already been formed to nurture the continuity of this work in this positive direction.

Technology Transferred: Through this work, infrared imaging in medicine was exposed to ever-growing audiences. For the first time, the work of the last two decades in this field was given a wider and more unified focus. By means of special tracks and workshops in international conferences organized by the Principal Investigator, this work sparked a significant and ever-growing interest in the capabilities of this modality. For example, from 1994 to 2000 the papers presented at these conferences increased significantly; many academic and DOD medical centers initiated clinical investigations using infrared imaging.. This triggered renewed interest in taking another look at the potential medical market. Manufacturers of IR cameras were appraised of this development

1. PROBLEM DESCRIPTION

Infrared imaging in medicine was discontinued as a mainstream modality in the United States in the 1970s, after a very enthusiastic beginning in the 1960s. For example, as early as 1973 IR imaging was included in research studies on breast cancer conducted by the National Cancer Institute at NIH. At that time, they proved inconclusive and eventually were dropped from the testing. However, some of those researchers who continued the work have since published promising results in breast cancer and stated that the failure of the original tests was due to inadequate training in thermography and physiology of the researchers. Furthermore, it was conducted with inadequate equipment, with little awareness of the scope and limitations of infrared technology, and with poor understanding of the underlying physiological and pathophysiological manifestations it can measure. This was a typical example of a premature use of a technology in medicine which resulted in it being discredited by the majority of the medical community. However, the true believers in this technology continued their efforts in this important research, and today we have significant findings which support this revitalized effort that has been further strengthened by the currently available superior infrared technology.

The present program was based on the premise that by:

(1) a) Continuing to develop teaming arrangements between manufacturers and medical centers for ensuring availability of cameras for initial clinical trials, b)monitoring results of quantification of clinical data at relevant academic centers one could ensure that there be some standardization of methodology in order to provide reproducible and reliable results. Moreover, it could put academic centers in touch with those who have worked for many years in their chosen application of medical IR imaging. This would provide the know-how and lessons learned and form the basis for continued work.

(2) Assisting in defining image processing techniques required for interpretation and standardization of medical images and by assisting in the transfer of DOD state-of-the-art computer technology it would be highly useful in the clinical area. A preliminary attempt would be made to assess ATR technology and smart algorithms that can be integrated into IR camera systems in order to enhance imaging performance.

(3) Participating in international meetings and workshops one might insure standardization of systems, methodology, and training, and the keeping abreast of all new developments and findings. Moreover, all of this could be coordinated with those carrying out the clinical work.

(4) Completing work on the two special issues of the IEEE/EMBS Magazine as discussed above, it would provide tremendous exposure for this modality and its authors and allow for easily accessible literature.

(5) Continuing the organizing of the annual medical infrared imaging track at the IEEE/EMBS International Conferences, and organizing and conducting the annual workshops would allow for an ever stronger collaboration and cohesive effort on the part of those participating.

2. SUMMARY OF MOST IMPORTANT RESULTS

The overall objective of this two-year contract was to generate impetus for the acceptance of infrared imaging as a valid, viable, highly successful low-cost diagnostic and screening modality in both military and non-military medicine. The effort during this period was focused on spurring new initiatives, and developing teaming arrangements, as well as quantification of clinical data, and continuing to organize workshops, mini-symposia and tracks for IEEE/EMBS and other conferences, presenting briefings to key decision makers and conferences, and organizing Special Issues on infrared imaging in medicine. The following are some highlights from this effort:

2.1. **Ville Marie Breast Cancer Research Proposal:** Ongoing discussions with Dr. John Keyserlingk, Director of the Center, led to the Center writing a proposal in response to the Medical Research and Materiel Command BAA on the Breast Cancer Research Program. I assisted them by providing inputs on infrared technology, instrumentation, methodology and clinical data analysis. This proposal covered a four year research study unique in the use of infrared imaging as an important adjunct to mammography and ultrasonic imaging for breast cancer. It was estimated that they would evaluate 4,000 patients a year which would total 16,000 by its completion. Their preliminary clinical studies indicated that infrared imaging used on patients along with mammography increased the probability of detection by 10 - 15%. The proposal successfully passed the three stages of evaluation. However, it was not funded because there was some concern that the IR technology used at Ville Marie did not appear to be state-of-the-art. With our assistance, they have now upgraded their imaging facility with advanced state-of-the-art IR camera and image processing systems. Moreover, they formed a research foundation funded by Canadian non-government sources for the sole purpose of carrying out advanced research in women's health. Infrared imaging is centrally used for this purpose, along with other modalities, for diagnostic enhancement in breast cancer. When they changed directors in 1994, we were instrumental in persuading them to continue using infrared in their clinic and referral center. This has led to important clinical findings in this area and to well received publications available in literature. This is significant because infrared imaging is finally receiving serious consideration. (Center's website is www.breastinfrared.com).

2.2 MEDIRIM (Medical Infrared Imaging) Program: This became a new initiative which was triggered by my briefing at the ATACCC Conference in Ft. Walton Beach, FL.; this was followed by in-depth discussions with one of the attendees, Dr. Franklin Porath, Director of Project Development, Ohio Aeronautical Institute, Cleveland, OH. As a result of my interaction with him, the MEDIRIM Program.was developed with the purpose of using infrared imaging in the detection and quantification of angiogenesis related or associated with tumors. Dr. Porath formed a consortium of industry, medical, academic and government partners to collaborate in this endeavor. Those present at the initial meeting came from The Angiogenesis Foundation, General Electric Medical Systems, Lockheed Martin, NASA, Cleveland Clinic, Blue Cross Blue Shield, Case Western Reserve University, OAO Corporation, and Advanced Concepts Analysis, Inc. A collaborative White Paper was drafted for funding. The program was designed to cover a three year period and,at the suggestion of FDA, it would initially concentrate on animal studies and would follow these with human ones.

The MEDIRIM Consortium, of which Advanced Concepts Analysis is a key player, continues the effort to obtain grants for the investigation of the use of IR imaging in the quantification of angiogenesis as a precursor to breast and other tumors. Preliminary investigations in animal studies are underway. Several proposals have been submitted to National Cancer Institute (NCI) and the CDBCRP at MRMC for grants to expand this work into clinical trials, which would also include antiangiogenic agents. The benefits of using infrared imaging for detecting angiogenesis at an early stage of the tumor will be central to these programs. Further, a MEDIRIM proposal is in progress to initiate an effort to integrate infrared imaging in telemedicine with DICOM compliance for military applications. This proposal has been revised several times and will be re-submitted to MRMC.

The National Cancer Institute (NCI) has identified anti-angiogenic therapy as a research priority with more intramural and extramural programs in this area. We arranged for Dr. William Li, Medical Director, The Angiogenesis Foundation, to speak on this subject at FDA. The benefits of using infrared imaging for detecting angiogenesis at an early stage of the tumor were central to the presentation. This seminar was very successful and was well attended by people from FDA, NIH, universities and other medical centers.

Today, pharmaceutical companies are developing a large number of anti-angiogenic drugs for inhibiting tumors. Infrared imaging can present them with a non-invasive, non-ionizing modality which has the potential to detect angiogenesis at a very early stage and which can validate the efficacy of these drugs in tumor control. In fact, last September, at the European Congress of Thermology in Italy, there were many pharmaceutical companies attending and actively supporting infrared imaging in medicine

Another collaborative effort under this program was to visit selective U.S. Congressmen's and Senators' medical staffers in order to educate them on the benefits of this modality for medicine and to request that Infrared Imaging be included in their congressional language to NIH as an additional imaging modality. This visit led to an invitation from the Congressional Women's Caucus to MEDIRIM to give a presentation on this subject. This took place on June 26, 2000. The relevant flyer is in Appendix A.

2.3. NIH Initiating Melanoma Studies Using Infrared Imaging: We are working with camera manufacturers and NIH for the setting up of studies by NIH in the area of early detection of melanoma (skin cancer). We are in the process of arranging with different manufacturers to provide infrared camera systems for this preliminary investigation. The study will include low cost uncooled and high performance cooled cameras so that these may be compared as to performance in clinical evaluation. In addition, the effectiveness of different wavelengths, such as 3-5 um and 8-12 um, will be compared and evaluated. This is of great importance for the validation of infrared imaging in medicine.

2.4 **NASA and Dynamic Area Telethermometry (DAT):** Three years ago we visited the NASA Jet Propulsion Laboratory (JPL), specifically Dr.Sarath Gunapala, and asked him to present a paper at the IEEE/EMBS conference in Amsterdam. Naturally, we spoke to him about the dual-use potential (using the

Quantum Well Infrared Focal Plane Array Camera for medical use). We made an arrangement for JPL to loan this camera to selective medical centers. One of these was the State University of New York (SUNY) specifically for Dr. Michael Anbar to use in his DAT research. This concept employs a high performance IR camera capable of high frame rates for performing FFT analysis to investigate hemodynamics associated with microvascularization related to pathophysiological abnormality and expressed as a thermal skin temperature. Recently, the NASA News had a press release on this concept. Advances in this research continue to be presented at the IEEE conferences and symposia, which we organize. The DAT concept is in the process of being validated by Omnicorder Inc. at several medical centers for the purpose of commercialization.

2.5 **BIOYEAR, Inc. Infrared Tomography:** Bioyear developed a high performance, uncooled camera system which has the capability to "slice" like tomography. This is achieved through an image processing software package developed through empirical modelling. The significance of this is the added capability of enhancing the specificity which most people view as lacking in infrared. We were given a demonstration of this and were asked to assist in proving its clinical efficacy. Subsequently, we reviewed the system design, modelling algorithm and documentation, and found them technologically sound. Hence, we arranged for this system to be evaluated in two prominent medical breast cancer centers where infrared is already being used in their screening and diagnostic procedures. These are: The Elliott Research Mastology Center, Baton Rouge, LA, and The Ville Marie Women's Health Center, Montreal, Canada. The clinical quantification is ongoing and we expect to have promising preliminary results shortly. Papers will be published on this once the clinical work is analyzed.

2.6. **Website of IR Images:** The purpose of this project was to develop a website of standardized images to be exchanged among the three medical research centers, which have experts in this field, in order to establish a baseline. The collaborative evaluation of these images will allow the development of a standard pattern for differentiation between normal and abnormal (malignant) thermal signatures as depicted by infrared imaging. This work will seek to validate this imaging modality as an important method of early detection of developing abnormalities associated with tumor growth in the breast and other areas.We are making arrangements with the three breast cancer centers (Ville Marie, Elliott Mastology Center and Therma-Scan, Inc.) to exchange images among themselves through the means of a dedicated website. This website will be hosted at the Air Force Virtual Distributed Laboratory. These arrangements are in process. This website of breast cancer IR images will be used for the purpose of establishing a uniformity of image interpretation to become a basis for standardization and training. This is the first step for the development of a large database with thermal signatures of malignant and non-malignant breast tumors. Biostatistical analysis of these images will provide the means of designing smart algorithms for the automatic detection of breast cancers. A workshop to discuss all issues is in the planning stage.

2.7. **Medical Image Processing Techniques:** Another issue addressed is the image processing techniques required for interpretation and standardization of medical images. It entailed the development and selection of appropriate algorithms that can be integrated into the camera systems.and the coordination with manufacturers for the adoption of these innovations as they are developed. This is in line with the future military medicine requirements, such as telemedicine now being developed by the Services under the leadership of the US Army Medical Research and Materiel Command. Some effort is underway for optimizing certain image processing techniques for specific ailments, examples of this are: (1) the work going on at the University of Arizona, in collaboration with the Elliott Mastology Center, which is focusing on developing advanced infrared imaging for breast cancer risk assessment. The image processing work was found to be extremely important and it was studied separately under another initiative.

2.8. **Special Issues on Medical IR Imaging:** The topic of "Infrared Imaging in Medicine" was selected for two dedicated special issues of the IEEE/EMBS Magazine. This was prompted by the increased interest in this area. Each issue contains ten or more extended articles on the subject. This gives great exposure to the IR imaging modality through 1)the 15,000 members of EMBS 2) its contents being included in the national medical databases, Index Medicus and MEDLINE.. The Principal Investigator responsible for this task was the Guest Editor for these publications. By way of information, the IEEE/Engineering in Medicine and Biology Society is the largest organization of biomedical engineers in the world. The magazine has the largest circulation of any biomedical engineering publication going to some ten thousand biomedical engineers, as well as academic institutions, industrial concerns, and libraries throughout the world, and is published six times a year. The special issues addressing specific technologies such as infrared imaging, are known to remain valuable reference sources for many years after the publication.
Two IEEE/EMBS Special Issues dedicated to Medical Infrared Imaging were published during this period July/August 1998 and May/June 2000.(Appendix B).

2.9. Conferences, Mini-Symposia and Workshops:

The following activities are attributed to the Principal Investigator of this project:

(1) Organizer of the Infrared Imaging Track, Mini-Symposia and Special Workshop, World Congress 2000, Chicago, July 2000. The Mini-Symposia consisted of six tutorial papers on aspects involved in the patho- physiological nature of medical infrared imaging. This was followed by two sessions of twelve papers and finally several papers were presented at the workshop, which was attended by 33 people. This workshop was supported by funding from ARO; the relevant report is contained in Appendix C.

(2)Organizer of the Infrared Imaging Track", 21st. Annual International Conference, IEEE/Engineering in Medicine and Biology Society, Atlanta, October 1999.

(3) Organizer and Co-Chair of a Special Workshop on Imaging: at the

21st. Annual International Conference, IEEE/Engineering in Medicine and Biology Society, Atlanta, October 1999. Papers on preliminary work started at various centers were presented. Naturally,the main purpose of this was to expand colloquium and exchange of ideas between international and national scientists, academia, and industry, who were present at the conference. It resulted in serious discussions and ideas of collaboration between them.

(4) Organizer & Co-Chair of the "Optical and Infrared Imaging Track", 20th Annual International Conference, IEEE/Engineering in Medicine and Biology Society, Hong Kong, October 1998. Highlights of the infrared imaging activities at this conference are contained in the attached trip report (Appendix D).

(5) Organizer and Co-Chair of a Special Workshop on Imaging: at the 20th Annual International Conference, IEEE/Engineering in Medicine and Biology Society, Hong Kong, October 1998. The purpose of this was to expand colloquium and exchange of ideas between international and national scientists, academia, and industry, who were present at the conference. It resulted in serious discussions and ideas of collaboration between them.

(6) Organizer and Co-Chair of an IR Imaging Workshop: This workshop took place at the Conference for Advanced Technology Applications to Combat Casualty Care (ATACCC-98), Fort Walton Beach, FL, November 1998. The theme of the workshop was the use of infrared imaging in combat casualty care appli cations and emergency medicine.

N.B. A sampling of e-mails received expressing the value of the above activities in the advancement of medical infrared imaging are attached in Appendix E.

2.10. Other Collaborations: Under this effort, other collaborations were spurred for important research in this area. Some of these are as follows:

(1) FDA was interested in researching the diffusion of laser energy in skin tissue and quantifying the results with infrared imaging. We arranged for them to collaborate with Dr. Kaveh Zamani, Walter Reed Medical Center, who provided the system to FDA. This work has been expanded to include a study on burns which is of interest to the military. It is expected that a paper will be published in the near future.

(2) Dr. Alexandra Boyd, Perth, Australia, contacted us in November 1998 and requested assistance in starting a clinical infrared imaging program in breast cancer. We provided information to her and invited her to the IEEE/EMBS conferences as a source of information and making pertinent contacts. Further, we introduced her to the American Academy of Thermology, The Elliott Research Mastology Center, Ville Marie Women's Health Center and Therma-Scan and arranged for the Directors to allow her to spend a few days in their clinics. As a result, she has made several important presentations to The Royal Australian College of General Practitioners, Royal Perth Hospital, Western Australian University. Another very important presentation was made to the World Health Organization (WHO) which supports the Key Center for Women;s Health Affairs at the University of Melbourne. They suggested that Dr. Alexandra Boyd investigate the role of infrared imaging in remote and

indigenous populations in particular. We are assisting her in this effort.

(3) Professor Hairong Qi, University of Tennessee (Knoxville), whom we met at a seminar arranged by Professor Wesley Snyder at North Carolina State University, had done some interesting work on image processing. We suggested that she use her algorithms on thermal images of breast cancer. For this purpose, we arranged for two breast clinics to provide her with the necessary thermal images for this study. She presented a paper on this work at the World Congress 2000, Chicago. We then encouraged her to continue this work and submit a proposal to the Congressionally Directed Breast Cancer Research Program at MRMC. This has been accepted and is being funded.

3.LIST OF PUBLICATIONS

3.1 Related Papers published in Journals and Proceedings by Principal Investigator:

(1) Diakides, N.A., Balcerak, R., "Emerging Uncooled Infrared Technology", Proc. European Congress of Medical Thermology, Brescia, Italy, Sep. 2000 (paper and trip report are in Appendix F)

(2) Diakides, N.A., (Guest Editor): Second Special Issue on Medical Infrared Imaging, IEEE/Engineering in Medicine and Biology Magazine, Vol.19, No.3, May/June2000

(3) Diakides, N.A., "The Growing Applications of Medical Infrared Imaging", IEEE/Engineering in Medicine and Biology Magazine, Vol.19, No.3, p.28-29, May/June2000.

(4) Diakides, N.A., "Quotations Digital Infrared Imaging in Medicine", Proc. ATACCC 1998 Conference, Ft. Walton Beach, FL, Nov.1998.

(5) Diakides, N.A. , (Guest Editor): Special Issue on Medical Infrared Imaging, IEEE/Engineering in Medicine and Biology Magazine, Vol.17, No.4, July/Aug.1998.

(6) Diakides, N.A., "Infrared Imaging: An Emerging Technology in Medicine, IEEE/Engineering in Medicine and Biology Magazine, Vol.17, No.4, 17-18, July/Aug.1998.

(7) Diakides, N.A., Diakides, M., "Advances in Infrared Technology, Proc.American Academy of Thermology, Fort Lauderdale, May 1998.

(8) Diakides, N.A., "Infrared Imaging: Improved Technology Ready for Clinical Applications", DARPA Uncooled Sensor Program Review, Alexandria, VA., Oct. 1998

3.2. Other Related Papers:

Additional related papers which were solicited by the Principal Investigator, during the course of this contract, for tracks organized and chaired by him are in the proceedings of the following conferences :

(1) World Congress 2000, Chicago, July 2000.

(2) 21st. Annual International Conference of the IEEE/Engineering in Medicine and Biology Society, Atlanta, GA., Oct. 1999.

(3) 20th. Annual International Conference of the IEEE/EMBS, Hong Kong, Nov.1998.

N.B. Abstracts of the above IR Imaging in Medicine papers are contained in Appendix G.

3.3. Presentations to High Level DOD Officials:

Briefed the Following Key People and Organizations on Medical Infrared Imaging: 1) TATRC, U.S. Army Medical Research and Materiel Command, Ft. Detrick, MD (31 August, 1998), (2) IEEE Baltimore Chapter, Johns Hopkins Medical Center, Baltimore, MD (10 September 1998)
(3) FDA, Rockville, MD (17 September 1998) (4) MEDIRIM Program Structuring Workshop, Ohio Aeronautical Institute (14 October 1998).

Briefed the Following Key People and Organizations on Medical Infrared Imaging: 1) Major General Parker, Commander, U.S. Army Medical Research and Materiel Command, Ft. Detrick, MD (March 18, 1999),
(2) Dr. Jasper Lupo, Director, Sensor Systems, OSD, Pentagon (several times),
(3) Briefed Dr. Stefan Morse, DARPA (DSO), Briefed Raymond Balcerak, DARPA (ETO) (4) MEDIRIM, Ohio Aerospace Institute, Cleveland, participated actively in forming this consortium.

4. CONCLUSIONS AND RECOMMENDATIONS

(1) Significant advances have been made in identifying potential applications for the effective use of infrared imaging in medical screening and diagnosis. Quantification of clinical data continues to be investigated in many medical centers in order to establish the efficacy of this modality. The interest and new initiatives in this field have increased significantly throughout the world and now include mainstream institutions. This has required a concentrated effort under these contracts which has allowed the nurturing of these interests. Many new initiatives are still in progress. These would be greatly enhanced by opening up funding sources of both government and private sources. Further, as witnessed by the progress to date, the conferences, workshops, seminars and special issues are of vital importance and should definitely be continued. They provide an effective professional environment for research and publications and a focal point to energize the overall effort.

(2) There is a critical need to develop suitable image processing techniques to assist in the standardized interpretation of the medical images. One promising approach is to use ATR technology coupled with "smart" algorithms uniquely designed to detect and recognize medical abnormalities based on thermal signatures. Hence, in order to achieve this capability, it is necessary to create a database with a sufficient number of patients to provide meaningful statistics upon which to base the algorithm design. The "targets" in medical applications are locally circumscribed lesions and may be superficial such as melanoma or deeper such as ductile carcinomas of breast cancer. Enhancements in the above technologies have strong potential to assist medical screening and diagnosis.

(3) The following topics are highly recommended for inclusion in a comprehensive future program:

- IR Imaging Methods: There are several methods which today are being used in the investigation of IR imaging interpretation. These include static, dynamic, and IR tomography (slicing). Quantification of these methods with statistically meaningful results could lead to establishing a very important medical system.

- Thermal Signature Database: Need to develop a database containing a large number of patients. Need to quantify and classify normal versus abnormal thermal signatures across a spectrum of different age groups with significant biostatistical analysis of these signatures. Characteristic signatures need to be identified and used for training of physicians, for standardization of protocol and for an objective interpretation of the image to assist the early diagnosis (malignant versus non-malignant).

- Image Processing: Design smart algorithms based on the above database to develop medical ATR for assisting in the image interpretation.

- Hyperspectral/Multispectral Imaging: There is a need to evaluate the efficacy of these imaging modalities for several critical medical applications.

- Multimodality and Sensor Fusion Imaging: It is necessary to investigate the advantages of both approaches as related to image processing and interpretation.

- Future camera designs should be toward small portable, low-cost, non-invasive, patient friendly device for both military and non-military applications, early detection of tumors and other pathophysiological abnormalities. A physician friendly method which cam be used in a multi-modality setting to assist in early diagnosis of critical medical abnormalities.

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APPENDIX A

MEDIRIM
CONGRESSIONAL WOMEN'S CAUCUS PRESENTATION FLYER

MEDIRIM

"Tools for imaging angiogenesis are critically needed to help advance the frontiers of cancer diagnosis and treatment."
W. Li, M.D., Angiogenesis Foundation

"Infrared imaging is a women friendly modality, with the potential to save lives through the early detection of angiogenesis."
N. Diakides, Ph.D., Advanced Concepts Analysis, Inc.

"Development of advanced infrared imaging for early detection of breast cancer will allow interventional therapy with curative potential."
J. Head, Ph.D., Mastology Research Institute

"MEDIRIM integrates defense and space technology with advanced medical technology to create a non-invasive, painless, and cost-effective system to fight breast cancer."
M. Salkind, Ph.D., OAI

SPONSORED BY:

The Angiogenesis Foundation

ACA Advanced Concepts Analysis, Inc.

FSI FLIR SYSTEMS

Breast Oncology The Elliott Mastology Center

OAI Leveraging Resources through Collaboration

FOR MORE INFORMATION:

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MEDIRIM

Earlier Detection

Earlier Treatment

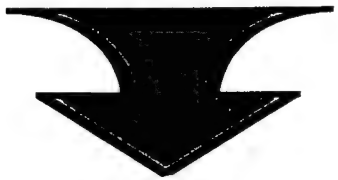
Presented to the
Congressional Women's Caucus
June 26, 2000

Vision for MEDIRIM

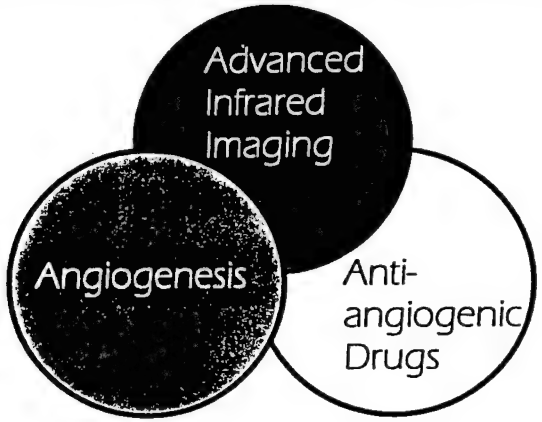
MEDIRIM's vision is to create a system for the integration of angiogenesis visualization by advanced infrared imaging and earlier treatment with antiangiogenic drugs for cancer intervention, including breast cancer.

The potential results are dramatic:

- Earlier detection
- Earlier intervention



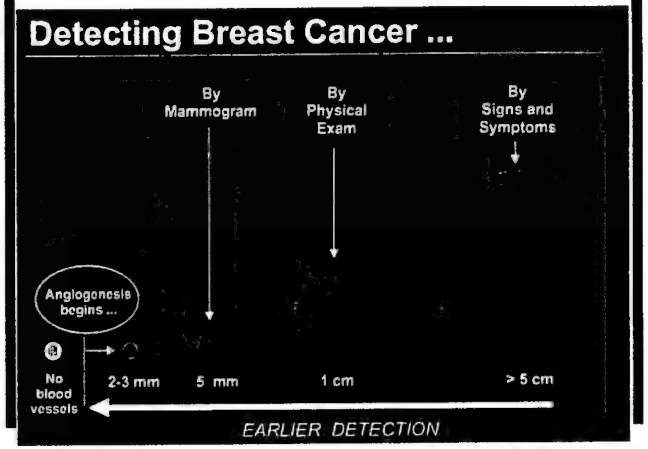
- Women's lives saved
- Reduced health care costs, potentially $5 Billion/year.



What is Angiogenesis?

Angiogenesis is the early development of blood supply which enables a tumor's rapid growth.

- Angiogenesis offers new opportunities for early detection and effective treatment of cancer.
- Technologies that can image angiogenesis are critically needed.
- Detection, treatment, and monitoring of angiogenesis is a new approach to cancer.



RESEARCH NEEDED

The MEDIRIM project is in its infancy with great potential to create an affordable, painless screening modality combined with an effective early treatment.

The goal of the MEDIRIM team is to bring together

- angiogenesis research,
- advanced infrared imaging technology,
- analysis software,
- advanced antiangiogenic drugs,
- test the system in a clinical setting,
- cost effective global screening, and
- telemedicine capability.

The DoD Connection

This advanced infrared imaging capability is the same sort that allows the Army to detect an enemy tank 2 miles away. If focused within 2 feet, it could be used to detect medical conditions, such as angiogenesis associated with a growing tumor. This offers potential dual-use and DoD technology transfer opportunities.

The NASA Connection

NASA's telemedicine capability to transmit images via satellite would allow screening in remote and underserved locations and for U.S. forces overseas.

APPENDIX B

SPECIAL ISSUES
COVERS, LIST OF PAPERS, PAPER GUEST EDITOR

IEEE
EMB

ENGINEERING IN MEDICINE AND BIOLOGY

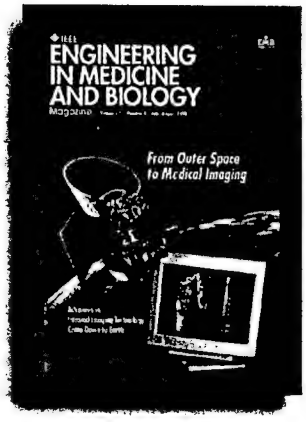
Magazine Volume 17 › Number 4 July/August 1998

From Outer Space to Medical Imaging

Advances in Infrared Imaging Technology Come Down to Earth

IEEE
ENGINEERING IN MEDICINE AND BIOLOGY
Magazine Volume 17 ○ Number 4 July/August 1998

Theme Section



Up Front

We shall not scorn what was done yesterday because we have something better today any more than our interest in the past will cause us to continue the practice of the past.

W. Wayne Babcock
Textbook of Surgery, Preface

Cover Credit: The original intent for infrared technology was for space exploration/astronomical observations and military purposes (shown here is the NASA's Infrared Astronomical Satellite (IRAS)). Advances made in the technology through the R&D efforts of NASA and the U.S. Department of Defense are now available for medical-imaging applications (shown on the computer is a infrared thermogram of the lower limbs of a human). IRAS image courtesy of NASA/JPL/Caltech. Medical thermogram courtesy of John Richard Harding, Royal Gwent and St. Woolos Hopsitals. Computer, ©PhotoDisc 1991.

From the Guest Editor

Infrared Imaging: An Emerging Technology in Medicine

Nicholas A. Diakides
Advanced Concepts Analysis, Inc.
Falls Church, VA

Infrared Imaging is now at the peak of its capability due to the great advancements made in this technology through the research and development efforts of the U.S. Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA). The original intent for developing this technology was purely military: primarily target acquisition, reconnaissance, surveillance, etc. Space exploration and astronomical observations were other major objectives. The spin-off was breakthroughs in infrared (IR) detector materials, focal plane arrays, advanced read-out circuitry, and smart image-processing algorithms. These were then integrated into high-performance IR systems. For example, it is common knowledge that advanced IR sensors gave the U.S. and allied forces tactical superiority in the 1991 Gulf War. Now this unique technology, which is in the forefront for dual-use, is available in all its maturity also for the medical-imaging field.

Infrared imaging is a physiological test that measures the physiology of hemodynamics and of the autonomic nervous system by means of a precise temperature measurement. Unlike imaging techniques such as X-ray radiology and CT that primarily provide information on anatomical structures, IR imaging provides functional information not easily measured by other methods. Correct use of IR imaging requires, therefore, in-depth physiological knowledge for its effective interpretation.

Infrared imaging is utterly noninvasive, as it passively monitors radiant heat emitted by the human body. Hence, it is absolutely risk free, unlike X-rays or even MRI or ultrasound, and it is relatively inexpensive and can be readily used as an adjunct to other standard imaging methods.

Current and potential uses of IR imaging in medicine are in the areas of neurology, vascular disorders, arthritis and rheumatism, pain (management and control), surgery, neonatology, oncology, tissue viability, emergency medicine, dermatology, ophthalmology, and dentistry. This clinical testing modality has been recently applied in the following areas: (1) open-heart, organ transplant, and reconstructive surgery (e.g. IVA 2000 General Electric Thermal Coronary Angiography System for open-heart surgery); (2) neonatal care and early diagnosis of neurological and metabolic disorders; (3) screening for breast and skin cancer; (4) staging of management of diabetes mellitus and liver disease; and (5) soft tissue and skin injury.

There are good opportunities for the medical and biomedical engineering communities to conduct innovative research in many areas of infrared imaging, ranging from clinical trials to quantify IR imaging data for various applications, intelligent image processing to enhance interpretation of images, development of user-friendly high-resolution IR cameras, to defining system specifications for establishing requirements in training and standardization. All these are challenges that need to be addressed in order to give this modality the role it deserves in modern health care.

The United States pioneered the clinical use of infrared imaging in the late 1960s in neurology, surgery, oncology, dentistry, and dermatology. It became very popular at the start, but was conducted with inadequate equipment, with little awareness of the scope and limitations of infrared technology, and with little understanding of the underlying physiological and pathophysiological manifestations it can measure. This was a typical example of a premature use of a technology in medicine and it was thus discredited by the majority of the medical community. However, the true believers in this technology continued their efforts in this important research and today we have significant findings that support this revitalized effort, which has been strengthened by the currently available superior infrared technology.

In the last four years there has been a more cohesive international effort to consolidate knowledge, experience, clinical data, ideas of standardization and training, and to start collaborative initiatives

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for re-establishing the basis for the use of infrared imaging in medicine. For this reason, medical infrared imaging was introduced as an emerging technologies topic at the International IEEE/EMBS 1994 Conference in Baltimore. Since then, this effort has continued every year with ever-increasing presenters and audiences. In 1997 in Chicago, there were 30 papers on different aspects of medical applications, and there were two special workshops; one was exclusively on early detection of breast cancer.

As a result of this evolution, there will be a series of three special issues of *IEEE EMB Magazine* dedicated to this subject. The first issue is focused primarily on introductory and overview papers; the second and third issues will be exclusively on quantitative clinical results and methods, including system requirements and "smart" image processing.

This issue contains eight articles that were contributed by internationally known experts in the use of infrared imaging in medicine, IR technology, and systems. Francis Ring (UK) presents a paper that traces the development of temperature measurement based on his experience of thermal imaging used in his work in rheumatology and pharmacology. Michael Anbar (USA) reviews the state-of-the art clinical infrared imaging in the last five years (1993-1997) and covers recent developments in clinical thermology in many fields of medicine, ranging from general surgery to ophthalmology. Anbar emphasizes the importance of understanding the mechanisms of physiological dysfunctions that are manifested in dynamic thermal abnormalities. Iwao Fujimasa (Japan) describes novel pathophysiological expressions of infrared images and proposes methods of analyzing procedures of thermal images. Richard Harding (UK) presents his extensive work in the use of infrared imaging in deep venous thrombosis, coming up with definitive conclusions. Kunihiko Mabuchi (Japan) describes the development of an image-processing program capable of producing images of the temperature difference between the affected side and the corresponding contralateral healthy side of the body, demonstrating its diagnostic value in a clinical setting. Maurice Bales (USA) presents several clinical example of soft tissue injury and breast cancer de tection where the use of appropriat image-processing algorithms substan tially enhanced the diagnostic acumen o infrared imaging. Timothy White, et al (USA) discusses the latest technology o uncooled, low-cost infrared imaging which is of special interest to the medica users. Finally, Brian Harrison, et al., (Ja pan) reviews the status of medical infra red imaging in Japan.

It is an honor to have the opportunit to expose this important emerging tech nology to a large audience through thes special issues. I would like to acknowl edge the U.S. Department of Defense fo developing the infrared technology an for the continued support of ARO DARPA, OSD/DDR&E, and BMDO to ward the transitioning of this technolog to medicine. I am indebted to Al Wald fo his guidance, assistance and expert ad vice, which made this special issue possi ble. My appreciation and thanks also g to the authors for their excellent contri butions, and to the reviewers for thei time and comments.

Student's Corner

(continued from page 16)

ducted in these areas. Students may find work published by these groups to get a more detailed look at their investigations.

Dr. Theresa Good is an Assistant Professor of Chemical Engineering at Texas A&M University, College Station (http://www-chen.tamu.edu/CHEN/faculty/good). (http://www-chen.tamu.edu/CHEN/faculty/good)

Need BME Information on The Net?

The following sites provide details regarding conferences, programs, student competitions, databases, journals, software and jobs available in biomedical engineering. Be sure to visit them!

1. BME net (http://BME.www.ecn.purdue.edu/BME/)
2. EuroConference in Cell and Tissue Engineerin (http://www.cba.unige.it/Events/TissueEngineering/)
3. BioInformatics Home Page at the National University Singapore (http://www.bic.nus.edu.sg/banner.html)
4. First IEEE-EMBS "special-topic" conference (http://titl nextgeninter.net/itab-98.html)
5. Other upcoming IEEE-EMBS conference (http://www.bae. ncsu.edu/research/blanchard/www embs/conferences.html)

For further information please contact Smita Sampath s0s5814@acs.tamu.edu or Mike McShane MCSHANE@ac tamu.edu.

NIST Lab Upgrades Scientific Data on the Web

NIST World Wide Web pages offering free and easy access to scientific data are among the institute's most popular, getting thousands of "hits" per month from computer users around the world. Now NIST has improved, expanded, and integrated the data offered on some of these pages into a new easy-to-use site: http://physics.nist.gov/cuu. This public resource provides in-depth information on the fundamental physical constants, the International System of Units (the modern metric system known as SI), and the expression of uncertainty in measurement.

Any computer user with access to the web can use this site to look up values of fundamental physical constants and conversion factors of physics and chemistry. These values are searchable in an easy-to-print form.

The metric information section contains a concise summary of the essential features of the SI, and the rules and style conventions for its use. In addition, the section details the seven SI base units and the 21 SI-derived units with special names and symbols. Electronic publications discussing use of the SI are also available.

The section concerning uncertainty covers evaluating and expressing the uncertainty associated with measurement results. A helpful publication from NIST and the citations of related publications of the International Organization for Standardization are posted in this section.

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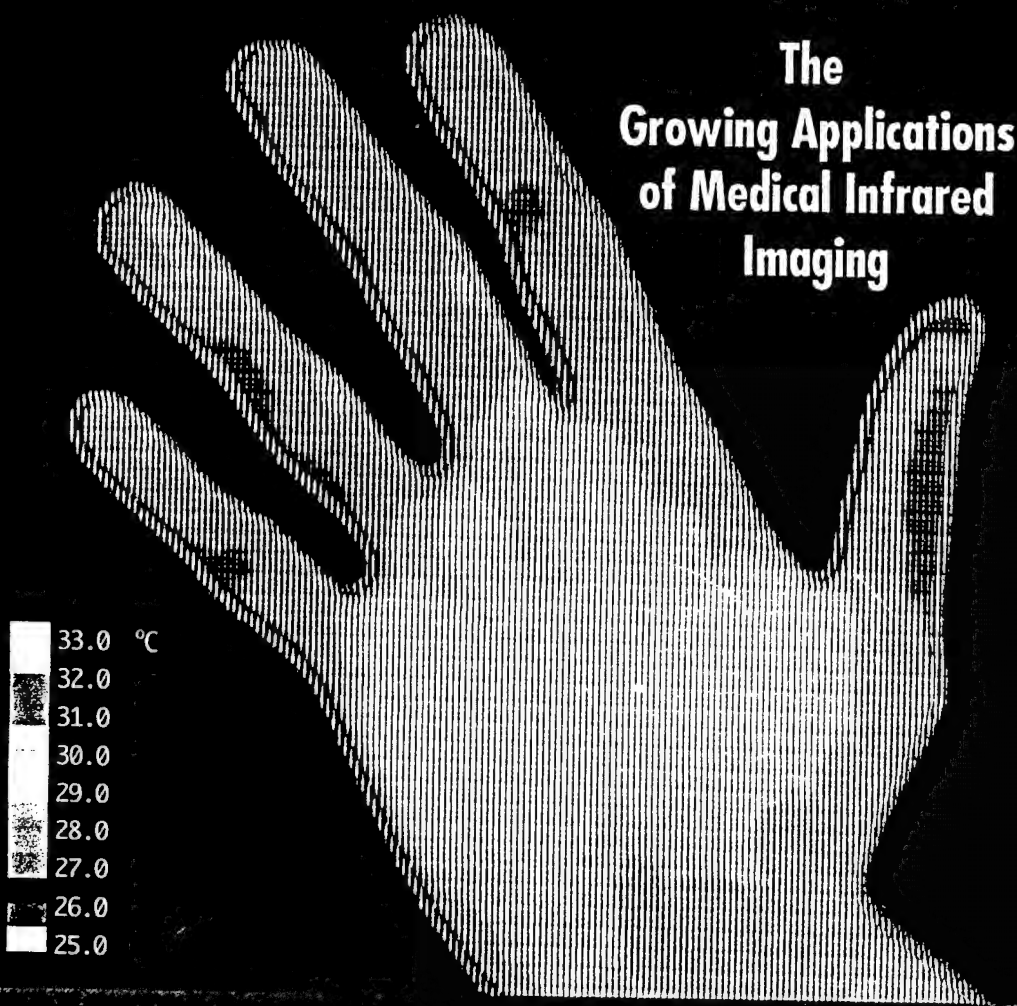
Magazine

Volume 19) Number 3 May/June 2000

Reaching for New Levels

The Growing Applications of Medical Infrared Imaging



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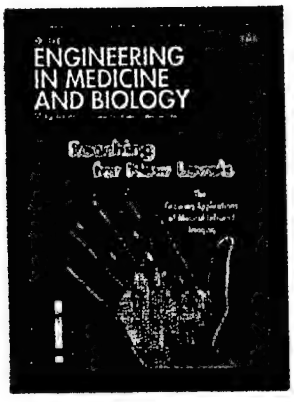
Theme Section

Advances in Infrared Imaging

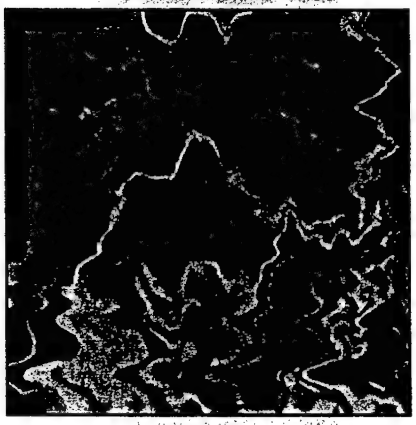


Up Front

Believing, as I do, in the continuity of nature, I cannot stop abruptly where our microscopes cease to be of use. Here the vision of the mind authoritatively supplements the vision of the eye.

John Tyndall [1820-1893]
Fragments of Science Vol. II: Address at Belfast (August 19, 1874)
British physicist

Cover: © Alfred Pasieka/Science Photo Library



From the Guest Editor

The Growing Applications of Medical Infrared Imaging

Nicholas A. Diakides
Advanced Concepts Analysis, Inc.
Falls Church, VA

It is a pleasure to have the opportunity to present further advancements in medical infrared (IR) imaging in this special issue on IR technology. Significant progress has been made both in technology and clinical research since publication of the first special issue on this topic (*IEEE EMB Magazine*, vol. 17, no. 4, July/August 1998).

In the technological field, the development of IR cameras with focal-plane arrays not requiring cooling has added a new dimension to this imaging modality. New detector materials with improved thermal sensitivity are available and production of high-density focal-plane arrays (640 × 480) have been demonstrated. Advanced read-out circuitry for focal-plane arrays using on-chip signal processing has become available. These breakthroughs permit low-cost and easy-to-use camera systems with thermal sensitivity approaching 50 milli-Kelvin degrees as well as a spatial resolution of 25-50 micrometers, given the appropriate optics. Another important factor is the emerging interest in the development of smart image-processing algorithms to enhance the interpretation of thermal signatures. In the clinical area, new research addresses the key issues of diagnostic sensitivity and specificity of IR imaging, and efforts are underway to achieve quantitative clinical data interpretation in standardized diagnostic procedures.

The first special issue on IR in medicine was received with significant interest from many sectors. That issue was mainly an overview; the present issue contains specific quantitative clinical applications in breast cancer, open heart surgery, and image processing. Articles were contributed by experts with many years of experience in using this modality in clinical settings.

Keyserlingk, et al. (Canada), discusses the advantages of adding IR imaging as an adjunct to mammography for breast cancer screening. The article reports a 10% increase in sensitivity when combining these modalities. Ohashi and Uchida (Japan) report results from 728 patients with breast cancer and 100 patients with normal breasts using steady-state and dynamic (sequential and subtraction) thermography. They conclude that the dynamic method offers an increase in diagnostic sensitivity of 28% over the static, bringing the overall sensitivity of detection to 82%. Head, et al. (USA), reports that their study demonstrated that an otherwise normal patient with an abnormal IR image of the breasts is at high risk for breast cancer and that a breast cancer patient with an abnormal IR image has a poorer prognosis. In addition, they state that second-generation IR imaging systems produce higher-quality images that potentially increase the value of IR imaging in breast cancer detection and treatment. Anbar, et al. (USA), discusses the use of dynamic area telethermometry (DAT) in assessment of breast cancer. This method focuses on quantitative or pathophysiological information. Snyder, et al. (USA), proposes an image-processing algorithm to increase the effective resolution of IR images by a factor of 2 while removing the noise and preserving edges in the image. This methodology is based on a minimization strategy known as mean-field annealing. Fujimasa, et al. (Japan), discusses the correlation of skin-surface temperature to physiological functions that control body temperature. They state that by using an appropriate algorithm, an IR image of the body surface can be converted from thermal to other physiological information.

Szabó, et al. (Hungary), used cardiothermography to monitor coronary perfusion through epicardial heat-emission changes. IR imaging proved to be effective in detecting epimyocardial temperature changes in hypothermia; hence, arterial graft patency and the integrity of the distal saphenous anastomosis could be safely and easily assessed. In the second article by Szabó, et al., thermography was used to evaluate the adequacy of myocardial protection employing Bretschneider cold antegrade cardioplegia in patients undergoing coronary bypasses or aortic mitral-valve implantations. They concluded that this technique reduced the risks associated with these surgical procedures.

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The current clinical results show the potential of IR imaging in several areas in medicine. However, as in all emerging technologies, this field calls for further investigation and quantification. This should be vigorously pursued since it could lead to a very useful, noninvasive, nonionizing, low-cost imaging modality in medicine, which could be used alongside other existing techniques

I would like to acknowledge the US Department of Defense for developing the IR technology and for the continued support of the Army Research Office (ARO), Defense Advanced Research Projects Agency (DARPA), and the Office of the Undersecretary of Defense (Science & Technology) toward the transfer of this technology to medicine. I am indebted to Al Wald, Editor-in-Chief of this magazine, for his guidance, assistance, and expert advice in making these special issues possible. My appreciation and thanks also go to all the authors for their excellent contributions and to the reviewers for their time and comments.

Nicholas A. Diakides received a D.Sc. (1979) in electrical engineering (medical engineering) from George Washington University. He is president of Advanced Concepts Analysis, Inc. (1989-present), which is a consulting firm dealing with advanced biomedical technology and innovative defense research. Currently, he is involved in analysis and assessment of sensor systems and biomedical technology for the Office of the Secretary of Defense (ODUSD-S&T and DARPA). In addition, since 1994 he has led the effort to establish internationally the use of advanced digital infrared imaging in medicine. Previously, he was director of the US Army Laboratory Command's Survivability Enhancement Division (1984-1989). From 1962-1983 he was program manager for various areas of IR technology and electro-optics at the Army Night Vision and Electro-Optics Laboratory. He has published more than 40 papers and one book chapter (invited) in the *Electronics Engineers Handbook*. Professional Activities: IEEE EMBS, publicity chair and member of the conference and technical program committees in Baltimore (1994); chaired tracks, sessions, workshops, mini-symposia on medical infrared imaging for IEEE/EMBS international conferences (1994-1999); member of EMBS Industrial Relations Committee (1999-present); IEEE-USA, member of the following two committees: Healthcare Engineering Policy (1989-1994) and R&D Policy (1994-present); and guest editor, *IEEE EMB Magazine* special issue on Medical Infrared Imaging (July/August 1998). He is a Fellow of the American Institute of Medical and Biological Engineering and a member of the Executive Committee of the American Academy of Thermology (1998-present).

Address for Correspondence: Nicholas A. Diakides, D.Sc., Advanced Concepts Analysis, Inc., 6353 Crosswoods Drive, Falls Church, VA 22044. Tel: +1 703 914 9237. Fax: +1 703 914 1636. E-mail: diakides@erols.com.

APPENDIX C

REPORT ON WORKSHOP, WORLD CONGRESS 2000, CHICAGO

WORKSHOP ON INFRARED IMAGING AT THE 22nd. EMBS ANNUAL INTERNATIONAL CONFERENCE (CHICAGO, OCT. 26, 2000)

by

Nicholas A. Diakides
Program Director
IEEE/EMBS

for

Army Research Office
P.O. Box 12211
Durham, NC 27709-2211

October 18, 1999

Grant No. DAAD19-00-1-0522
(Proposal No. P41608-EL-CF)

WORKSHOP ON INFRARED IMAGING AT THE 22nd. EMBS ANNUAL INTERNATIONAL CONFERENCE

INTRODUCTION

The Workshop on Infrared Imaging at the 22nd. IEEE/EMBS Annual International Conference in Chicago was held on July 26, 2000. This is a multi-society joint conference consisting of The American Institute of Medical and Biological Engineering, IEEE/Engineering in Medicine and Biology Society, The International Conference of Medical Physics, etc. The specific aims of this conference were to assess the current status and future potential of a number of new key areas of biomedical engineering, and define the directions of future research in these interdisciplinary areas. We organized two mini-symposia consisting of tutorials, two sessions, oral and poster presentations, on different topics on the use of infrared imaging in medicine. The purpose was geared toward establishing the acceptance of infrared imaging as an effective and necessary modality for use in military and non-military medicine. Infrared imaging is an emerging technology and has the potential of leading to multi-modality sensor systems for enhancing the screening, diagnostic, and therapeutic capabilities of future medical practice. Further, it could be used alone for certain applications such as those of a pathophysiological nature (functional and soft tissue imaging); a unique advantage since it is provided by a totally non-invasive, non-ionizing, and low-cost procedure.

Invited national and international speakers, experts in infrared technology and its clinical applications in medicine, made presentations summarizing the status and recent developments in their particular research areas in infrared imaging for medicine. The audience consisted of biomedical scientists, academicians, clinicians, physicians, industrial representatives, and policy makers in healthcare. The presentations preceded the informal workshop where panel discussions (with audience participation) of the key issues for advancing the acceptance and increased use of infrared imaging in medicine took place. The conference presentations will be published in the IEEE/EMBS proceedings, and their abstracts will be available in the National Library of Medicine Databases, MEDLINE and INDEX MEDICUS (a list of the IR Imaging presentations of the mini-symposia and sessions is attached.)

The conference was well attended by more than 6,000 participants from all over the world. The topic of the infrared imaging in medicine as an emerging technology was introduced at the IEEE/EMBS conference in Baltimore in 1994. Since then, the interest in this area has been significantly enhanced in broad circles of the biomedical and health care communities. New initiatives in clinical applications of this modality are currently being pursued, as are issues such as training and standardization.

Another very important spin-off from these conferences is the informal workshops which we initiated in Baltimore in 1994 and which now are being held every year. These are attended by all the participants of the tracks with the intent of promoting a closer working relationship and

informal, open dialogue and exchange of ideas between these national and international scientists, physicians, academicians, and industry. More and more, this has resulted in fruitful discussions and ideas of collaboration between them. Even more importantly, it further exposes in a direct manner the importance of developing the use of infrared in medicine. Several joint efforts have been initiated at these workshops with positive impact in this field. This year, the workshop consisted of several presentations of preliminary results of new research efforts as well as the usual open discussions.

DISCUSSION

The workshop began with introductory background presentations from the Co-Chairs, Nicholas Diakides, William Sander and Wesley Snyder, and a round-table introduction of the 36 participants and their affiliations. These were followed by five papers of new research on the following subjects (an agenda and a list of participants is attached):

(1) Dr. Keyserlingk, Ville Marie Women's Health and Medical Center, Montreal, Canada presented a paper entitled "Recent Cases of Clinical Findings of IR and Mammo Images Supported by Surgical Histology". He discussed the importance of adding infrared imaging of the breast as an adjunct diagnostic tool for women. He showed a comparison of IR with mammographic images where in some cases the results did not agree, but where infrared proved to be correct by surgical histology. This was opened up to group discussion.

(2) Professor Hishashi Usuki, Kagawa Medical University, Kagawa, Japan, presented "Standardization of Thermographic Breast Cancer Detection: Role of Qualitative Findings and Quantitative Findings". This dealt with a unique method for standardizing breast cancer protocols and comparing those that are being used presently. This work is of immense interest but has to be further validated with more quantitative studies.

(3) Dr. Phillip Hoekstra, Thermo Scan, Inc., Huntington, MI, talked about the "Development of Analytical Software Package for Clinical Thermology". This contained innovative approaches on software for enhancing the interpretation of medical images. The software package is of modular design and gives added flexibility for processing the images.

(4) Professor T. Togawa, Tokyo Medical and Dental University, Tokyo, Japan, presented outstanding results on "Imaging Techniques of Thermal Properties of the Skin". This information complemented a paper presented by Professor George Brengelman , University of Washington, Seattle, WA., on microcirculation and the autonomous nervous system as related to skin temperature.

(5) Professor Junji Wakamiya, Center for Minamata Diseases, Hama, Japan, "Standardization of Thermographic Diagnosis" which gave new information on detecting breast cancer using both qualitative and quantitative approaches.

After these presentations, the meeting was opened up to discussion and suggestions from all attendees. This is a very useful exercise for both the presenters and those in the audience because it often adds ideas and direction from others' experience. Drs. Sander and Snyder, ARO) discussed possible programs and university research initiatives related to image processing in IR. Ray Balcerak, DARPA, remarked that he was impressed with the work that was being done

with IR and would be sure to pass on this information to the camera manufacturers. In closing, Dr. Diakides announced the IR activities for 2001, including the IEEE/EMBS conference to beheld in Istanbul, Turkey (October 26-29, 2001) and projected the continued progress for IR imaging in the future (see attached).

CONCLUSION

This workshop created the possibility for scientists, physicians and government to come together to examine and discuss key issues for standardization, formalized protocols and to reach consensus for the quantification of clinical data for publication in well recognized medical journals. These requirement are essential for establishing IR imaging in medicine.

Sixth Annual Workshop on Medical IR Imaging
World Congress 2000, Chicago, IL

Chair: N.A. Diakides, Ph.D., Advanced Concepts Analysis, Inc., USA
Co-Chair: William Sander, Ph.D., Army Research Office, USA
Wesley Snyder, Ph.D., North Carolina State University, USA

Date: Wednesday, July 26, 2000
Time: 12.30 pm - 5.00pm
Place: Hyatt Regency Chicago, New Orleans Room

AGENDA

1.00 pm	Welcome/Introduction	Nick Diakides
1.10 pm	Introductory Remarks	Bill Sander Wesley Snyder
1.20pm	Round Table Introduction by Participants	All
1.40pm	"Recent Cases of Clinical Findings of IR & Mammo Images Supported by Surgical Histology" and Open Discussion by All	John Keyserlingk
2.40pm	"Standardization of Thermographic Breast Cancer Detection: Role of Qualitative and Quantitative Findings"	Hishashi Usuki
2.55pm	Break	
3.05pm	"Development of Analytical Software Package for Clinical Thermology"	Phill Hoekstra
3.20pm	"Imaging Techniques of Thermal Properties of the Skin" Discussion by All	T.Togawa, M.Hassan
3.35pm	"Standardization of Thermographic Diagnosis" Discussion by All	Junji Wakamiya
3.50pm	Open Discussion - Issues, etc.	ALL
5.00pm	Closing Remarks - Adjourn	Nick Diakides

World Congress 2000, Chicago
Infrared Workshop Attendees
July 26, 2000

Dr. William Sander
sander@arl.aro.army.mil

Prof. Wesley Snyder
snyderWE@arl.aro.army.mil

Dr. Jonathan Head
emcmri@iamerica.net

Prof. Kunihiko Mabuchi
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Raymond Balcerak
rbalcerak@darpa.mil

Dr. Arcangelo Merla
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Dr. K. Kondo
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Prof. Francis Ring
RINGF@rnhrd-tr.swest.nhs.uk

Dr. Richard Harding
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Prof. Bryan Jones
bfjones@glam.ac.uk

Prof. I. Fujimasa
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Dr. John Keyserlingk
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Ben Lamfers
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Dr. David Chang
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Dr. Nicholas Diakides
diakides@erols.com

Mary Diakides
diakides@erols.com

Prof. GianLuca Romani
glromani@itab.unich.it

Dr. Naoto Kakuta
kakuta@mels.ccr.u-tokyo.ac.jp

Infrared Imaging Activities

Current Year

World Congress 2000, Chicago (July 23-28)

- Two IR Imaging Sessions
  - Posters
  - Oral Presentations
- Two Mini-Symposia
- Seminar/Workshop

- IEEE/EMB Magazine Vol.19, No.3,May/June 2000 (2nd. Isssue dedicated to IR Imaging)
- Now soliciting papers for the 3rd. issue

Next Year - 2001

IEEE/EMBS International Conference, Istanvul

- Sessions
- Mini-Symposium
- Workshop/Seminar

Need papers in the following areas:

- clinical quantification data
- image processing/image interpretation
- multi-modality imaging
- standardization/training

APPENDIX D

HONG KONG TRIP REPORT

TRIP REPORT
(Hong Kong, Oct. 29 - Nov. 1)

To: U.S. Army Research Office
ATTN: AMXRO-AAA (Ms.Gloria Crews)
Research Triangle, Park, NC,

From: Nicholas A. Diakides
Advanced Concepts Analysis, Inc.
6353 Crosswoods Drive
Falls Church, VA 22044-1209

Subject: IEEE/Engineering in Medicine & Biology Society International Conference (Contract DAAG35-98-C-0035)

Date: January 4, 1999

Introduction:

At the end of October, I traveled to the above conference in Hong Kong in the capacity of a Treck Chair and Theme Co-Chair.Since 1994, we have used these annual conferences to bring together international physicians, biomedical engineers, universities and manufacturers involved in medical infrared imaging to present their latest clinical results/methodologies/ research, and to discuss relevant issues and possible future collaborations. As you know, this has been a very successful forum and has largely contributed to the progress we have today. Again this year, I organized a track entitled "Optical/Infrared Imaging" which had 30 papers (24 oral and 6 poster presentations). These are included in the conference proceedings (see attached abstracts). In addition, we planned a workshop where several invited papers were presented, followed by presentations on preliminary results of new military medicine initiatives and ending with the usual informal discussions and interchange (see attached agenda).

Further, we met with Professors Izzat and Yim, The Prince of Wales Hospital, Hong Kong, and discussed their infrared imaging facilities and methodology for open-heart surgery. We also met with the Program Chairman (Susan Blanchard, North Carolina State University) of next year's IEEE/EMBS conference with a view to raising the Infrared Imaging from a Track to a Theme status in the Emerging Medical Technologies.

Discussion:

The conference was attended by more than 1200 people from all over the world, with the majority from the Asian countries. Around 1000 papers were presented, both oral and posters. The Optical/Infrared Imaging Track drew many people. Infrared Imaging was new to many of them, especially the Chinese. However, we believe that this triggered their interest judging from the many questions they asked. I had extensive discussions with one of the attendees of the conference, Dr. Joseph Tritto, M.D., Surgeon and Neurologist from the Vatican, Rome, Italy. He then attended all the presentations and the workshop. His interest is the possible use of IR Imaging for screening breast and prostate cancer for the Vatican. We are following this up to see how we could help them to start some clinical studies in this area.

Some of the highlights of the papers presented were the following:

Dr. Harding's paper on "Infrared Imaging on Diabetic Foot Ulceration" highlighted some important findings from the preliminary study (49 patients) he undertook at San Woolos Hospital, Gwent, Wales. He showed that infrared imaging appears to be very sensitive in indicating at a very early stage the presence of osteomyelitis in the diabetic foot. This is of utmost importance in so much as antibiotic therapy is most effective if administered at the onset of osteomyelitis. In this, clinical diagnosis and radiological examination may not be effective since they do not appear to pick this up at this stage. A larger controlled trial is now underway, which will validate infrared imaging as a useful, non-invasive initial investigation to exclude or confirm osteomyelitis in patients with diabetic foot ulcerations. (In the London conference, September 1994, which we attended, Dr. Harding presented a Deep Venous Thrombosis Preliminary Study using liquid crystal. I was able to persuade Professor Francis Ring, The Royal National Hospital for Rheumatic Diseases, Bath, UK, to lend Dr. Harding an infrared camera to continue his clinical trials. According to him, he has "never looked back ever since then" and is one of the radiologists who has become a great advocate of medical infrared imaging.

Dr. Yuri Parisky, M.D., USC/Norris Comprehensive Cancer Hospital, Los Angeles, California, presented his results from a pilot study on breast cancer using infrared with a smart algorithm to differentiate between malignant and non-malignant tumors. 125 lesions were evaluated from 117 patients - these pathological evaluations revealed a total of 95 benign findings and 39 malignant findings. Of the proven malignancies, 12 were identified as "in situ" carcinomas, while the remaining 18 were invasive carcinomas. The preliminary conclusions are that algorithms appear to be able to distinguish benign from malignant breast cancers, which may lead to reduction of the number of benign breast biopsies with sacrificing accuracy.

Dr. Lisa Marcucci, (whom I recruited to present a paper in the Montreal conference in 1995 and who received a BMDO grant to continue as a result of this), wrote a paper on the use of IR imaging in endoscopic surgery for organ transplant. The authors of "Infrared Imaging in Minimally Invasive Surgery" conclude that IR imaging in specific endoscopic procedures enables enhanced detection of specific anatomy when compared with visible light imaging only.

Professor Fujimasa, National Graduate Institute for Policy Studies - University of Tokyo, reports that fusion of infrared images with visible images in order to allow the observation of the abdominal and chest cavity in studies of animals. This was done in order to evaluate the feasibility of this system for human clinical trials. The preliminary results show that overlapping thermal and visible images enabled him to obtain new information of tissue pathophysiological functions. Dynamic temperature change of selected tissues or organs were clearly traceable using this new method. Overlapped image with color thermogram is more suitable than greytone thermograms. This work will be continued in order to quantify the efficacy of this technique.

There are many other interesting papers which appear in the proceedings. A copy has been sent to Dr. William Sander.

The now "traditional" workshop was attended to full room capacity. This year we had nine presentations (see attached agenda) followed by open discussions. The presentation of papers in a workshop setting is very useful because it allows the presenters to interact directly with the audience. These were new studies that will help the adoption of infrared in various medical applications. This year, two of the papers were presented by military physicians introducing the use of infrared in combat casualty care.

Conclusions:

Once again, these conferences prove to be of great value in drawing greater and wider interest in the use of infrared imaging in medicine. They also act as a "hub" for the exchange of ideas, which oftentimes leads to collaborations. We are also able to reenergize goals and strengthen the purpose and basis of the clinical research required, such as standardization, controlled trials, etc. In addition, we set the basis for the following conference and ensure that medical infrared imaging remains as a viable track.

Fifth Annual Workshop on Medical IR Imaging
IEEE/EMBS International Conference, Hong Kong
October 31, 1998

Chair: N.A. Diakides, Ph.D., Advanced Concepts Analysis, Inc., USA
Co-Chairs: J.Freeman, M.D., HyperMed Imaging, Inc., USA
M. Hopmeier, Unconventional Concepts, Inc., USA

Date: Saturday, October 31, 1998
Time: 12 noon - 4.00pm
Place: Hong Kong Conference Center, Room 204/205

AGENDA

12.00 noon	Lunch	
12.45 pm	Welcome/Introduction	Nick Diakides
12.55 pm	Overview	Jenny Freeman
1.05 pm	"Technology Transfer"	Michael Hopmeier
1.15 pm	"Infrared Imaging: Improved Technology Ready for Clinical Applications"	Nick Diakides
1.35 pm	"Shortfalls in Conventional Medical Imaging: Where Do We Go From Here?" Michael Freckleton, M.D., Texas A&M Univ., USA	
1.55 pm	"Clinical Uses of Dynamic Infrared Imaging in the Study of Pathological Changes in Cutaneous Microcirculation" Michael Anbar, Ph.D., State Univ.New York, Buffalo,USA.	
2.15 pm	"Multispectral Infrared Imaging: Assessment of Tissue Viability and Tissue Hydration Following Surgery." Harry Mantsch,Ph.D., National Research Council, Canada	
2.30 pm	"Intraoperative Angiography in Off-Pump Coronary Artery Bypass Grafting" Anthony Yim, M.D., Mohammad Izzat, M.D., Chinese Univ of Hong Kong, HK	
2.45 pm	"Infrared Imaging of Burn Injuries" Michelle Park, M.D., Leopoldo Cancio, M.D., US Army Institute of Surgical Research, USA.	
3.00 pm	"Thermal Coronary Angiography Infra CAM-MED 5" (Video) N.March, M.D., J. Freeman, M.D., USA	
3.10 pm	"low-Cost Uncooled IR Camera System" Tim White, Lockheed Martin IR Systems, USA, Jenny Freeman, HyperMed Imaging, Inc., USA	
3.15 pm	Open Discussion/Issues	
4.00 pm	Adjournment	

APPENDIX E

SAMPLINGS OF E-MAILS OF APPRECIATION OF THIS WORK

Subject: Leaving LM
Date: Fri, 28 Jul 2000 13:42:07 -0400
From: "White, Tim" <tim.white@lmco.com>
To: "'Diakides, Nick'" <diakides@erols.com>

I wanted to let you both know that I have handed in my resignation. I am going to a start-up company which is making wireless headsets for cell phones.

Thanks so much for all you have both done to move IR technology into medicine. It is very satisfying to see the progress being made. I will be looking forward to hearing more and more as it moves into accepted research and then practice. I won't be in the field any more but will try to keep in touch. If you want to reach me for any reason I will be here through August 3 and then I will be at Aura Communication starting Aug 7. email address: tim@auracomm.com

Tim White
Lockheed Martin IRIS
2 Forbes Rd
Lexington MA 02421
phone 781 863-3119
fax 781 863-4193

Subject: RE: partial reimbursement expenses
Date: Tue, 01 Aug 2000 21:35:05 -0400
From: John Keyserlingk <jrkoncol@videotron.ca>
To: "Nicholas A. Diakides" <diakides@erols.com>

Dear Nick and Mary,

Congratulations for all your efforts to get the gang together. You both deserve a medal for all your good work to help quality control of a very important modality. Your organizational skills are much appreciated and we are all much indebted to you both for diligently putting together these meetings

My cases are ready for downloading.

Whatever expenses can e covered will be much appreciated by our accountants, particularly since preparing these cases added up to quite a bill from audio-visual. Let me know what needs to be done to get this support for the trip to Chicago.

Best regards. JK

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Beper (514) 988-7403
DR. JOHN R. KEYSERLINGK,
M.D., M. Sc., F.R.C.S. (C), F.A.C.S.
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Téléphone: (514) 933-2778 • Fax: (514) 933-9635

Attachment: Forwarded Message

Date: Fri, 21 Jul 2000 14:09:46 -0500
From: "William Erdman" <William:Erdman@email.swmed.edu>
To: <Diakides@erols.com>
Subject: Medical Infrared

Dear Nick,
Congratulations on the excellent IEEE publication. It seems infrared imaging is getting some much deserved attention . We had actually negotiated with Omnicorder to get a DAT breast unit for evaluation. I was quite interested mainly because of my discussions with you. Unfortunately the deal fell through. Nonetheless, I am still interested and greatly appreciate your thoughtfulness in forwarding (via George)the journal to me.

Best regards,

Bill

---

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THE UNIVERSITY OF TEXAS
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Subject: Re: [Fwd: Tvl Expenses]
Date: Thu, 3 Aug 2000 13:37:24 -0700 (PDT)
From: "G. Brengelmann" <brengelm@u.washington.edu>
To: "Nicholas A. Diakides" <diakides@erols.com>

Nicholas --

Hello from Seattle. We returned in one piece Sunday evening. Unfortunately, I've been ill since Monday afternoon -- have been in bed most of the time since. If I can get my act together I'll proceed with the expenses later today or tomorrow.

It was lovely meeting you and Mary at last, though frustrating not to have more time to talk to you one-on-one. I'm so glad you organized that workshop because of the opportunities to hear more on thermal imaging and, especially, to meet people. I was able to exchange a few words with Togowa on topics of great mutual interest, with the young cardiac surgeon from Germany, and with the men from Italy interested in thermal modeling. I only wish we had all had more time together.

George Brengelmann

Subject: **Thank you**
Date: Thu, 27 Jul 2000 19:13:21 -0400
From: Hairong Qi <hqi@utk.edu>
Organization: UTK
To: "Nicholas A. Diakides" <diakides@erols.com>
References: 1

Hello, Nick and Mary,

Just want to say thank you for your hard work in organizing the IR session, the symposium and the workshop. I learned a lot, especially from the symposium. It gives me a great chance to meet with people and talk about research. I hope their presentation will be on-line soon. If you need any help in putting them on-line, please let me know.

Also thank you for your encouragement and the help for me to get into the area quickly. I will keep on working hard and hopefully present good results next year.

Best regards,

Hairong

--
Hairong Qi, Ph.D.
Assistant Professor
Electrical and Computer Engineering
The University of Tennessee, Knoxville
Tel: 865-974-8527
Fax: 865-974-5483

Subject: Thermography in localised scleroderma
Date: Wed, 22 Nov 2000 14:32:07 -0000
From: "Kevin Howell" <kjhowell@rfhsm.ac.uk>
Organization: Rheumatology, Royal Free Hospital
To: <diakides@erols.com>

Dear Dr. Diakides,

It was a pleasure to meet you once again in Desenzano in September. Thank you for the copy of the journal you guest-edited on thermography: I've found it a very interesting read. I am very impressed at the success you are having in raising the profile of medical thermal imaging in the States.

My reason for writing is that I promised you I would send you a copy of the paper I presented in Italy on localised scleroderma in children. My apologies for not doing this yet. However, now I can show you this paper easily because it has just been published in Kurt's journal, Thermology International, volume 10 issue 4. I expect you receive this journal and might have a copy by now, but if not let me know and I will mail you the article.

With kind regards

Kevin

Kevin Howell
Clinical Scientist
Centre for Rheumatology
Royal Free and University College Medical School
Royal Free Campus
Rowland Hill Street
London NW3 2PF
UK
Tel.+44 (0)20 7794 0500 x 4874 or bleep 1233
Fax +44 (0)870 1331058

Subject: Re: [Fwd: My IR research]
Date: Tue, 2 Feb 1999 11:42:04 -0500
From: "Nitish V. Thakor" <nthakor@bme.jhu.edu>
To: "Dr. Nicholas Diakides" <diakides@erols.com>
CC: sander@aro-emh1.army.mil, hpollehn@arl.mil, ngupta@arl.mil

I received the following communication from Dr. Diakides. I am excited by the possibility of collaborating on medical application of IR camera technology. If you have such an interest, we would be pleased to explore such projects, clinical application and commercialization with you. There are numerous possiblities at the Johns Hopkins Medical Institutions. One of which is the formation of a National Science Foundation funded prestigious Center fo Computer Integrated Surgery where I am exploring surgical application of IR. Other diagnostic applications in brain, heart, and tumor areas are also under consideration.

I hope to hear from you should there be a matching, collaborative or research/commercialization interest from you.

Nitish Thakor
Professor, Biomedical Engineering
Johns Hopkins Medical School

Tel: 410-955-7093
Fax: 410-955-0549

On Thu, 21 Jan 1999, Dr. Nicholas Diakides wrote:

> *Dear Colleagues:*
> *With reference to my previous conversations with you, I am forwarding the proposed research that Professor Nitish Thakor is intending to do with a viwe to your collaboration on this research. This would be of great valie to the medical field and I hope we can get something started.*
> *I have known Professor Nitish Thakor, Johns Hopkins University, for the last five years and I am very familiar with his outstanding research work and he is a strong supporter and user of infrared imaging in medicine. He is well known in the biomedical community throughout the world and he is a Fellow of IEEE and AIMBE (American Institute for Medical and Biological Engineering).*
> *Please contact Nitish Thakor directly. His address is:*
> *Professor Nitish Thakor*
> *Director, Biomedical Instrumentation & Computing Lab.*
> *Johns Hoplins University*
> *School of Medicine*
> *720 Rutland Avenue*
> *Bltimore, MD 21205*
> *Tel: 410 955-7083/ Lab: 410 955-0077*
> *Fax: 410 955-0549*
> *Best regards.*
> *Nick Diakides*

Subject: Thank you
Date: Thu, 11 May 2000 09:21:39 -0500
From: "Wang, Jing" <JWang@heart.thi.tmc.edu>
To: diakides@erols.com

Dear Dr. Diakides

I thank you for your help of my questions about IR thermal imaging of cell.
It was very helpful I have benefited a lot.

I have received your massage. Dr. Guo currently working for MediSpectra located at Lexington MA, as Senior Research Scientist. His telephone number is 781-372-2327, and his e-mail is bguo@medispectra.com.

My address is
Texas Heart Institute,
Texas Medical Center, MC 2-255,
PO Box 20345, Houston, TX 77225.
Phone # : 713-791-3487, Fax # : 713-791-4205.
e-mail jwang@heart.thi.tmc.edu

I will be keeping in touch with you

Sincerely

Jing Wang, Ph.D

Subject: Request Info
Date: Wed, 13 Sep 2000 12:39:27 +0100
From: Arcangelo Merla <a.merla@itab.unich.it>
To: diakides@erols.com

Dear Dr and Mrs Diakides,
thanking for your contribute to the 8th EMCT. With regard to the 8th EMTC works, I think that all the researchers that aim to promote the diagnostic use of IR imaging need to reach an agreement on protocols and methodological approach. I think that this is an important point in order to compare and exchange data more easily. All the impacted journals require papers with large number casuistry and homogeneity in the inclusion criteria that are hardly reached by single group and are time expensive. We need to propose works which compare IR and gold standard findings and, also, blind studies to convince sceptic people on the great possibilities offered by IR imaging. Very important is, in my opinion, a complete understanding of the thermoregulatory properties of the human body and its several parts also on the basis of mathematical and physiological modelling. Therefore, I think that a close collaboration has to be established among the several components that work with thermology as medical doctors, biomedical physicists and engineers and so on. So it is desirable a continuos and constructive discussion and exchange of ideas, methods and opinions.
I wish we keep open this discussion table also using the great possibilities offered by Internet.
Moreover, I would like to receive more detailed information about the possibility to partecipate to the projects that you have talked to me.
Looking forward to keep in touch, would you please accept my renewed invitation to visit our thermography laboratory.

Best Regards.

Dr Arcangelo Merla
Dpt. of Clinical Sciences and Biomedical Imaging
Inst. of Advanced Biomedical Technologies
University "G. D'Annunzio"
via dei Vestini 33
I-66013 Chieti, Italy
phone +39 871 355 6901/02/52
fax +39 871 355 6930/31

Subject: Thermal Imaging research
Date: Thu, 07 Sep 2000 10:08:44 +1000
From: Craig Berry <craigb@onthenet.com.au>
To: diakides@erols.com

Dear Sir,

We have been referred to you by the Ville Marie Institute. To briefly introduce ourselves, the Australian Thermology Association is a relatively new association representing thermographers in Australia. We also have our own thermal imaging clinic on the Gold Coast, Queensland, Australia (www.thermalimaging.com.au)

To help our education and instuction in the value of thermal imaging we are looking for any studies or research articles within the last 5 years using thermal imaging technology to assess musculo-skeletal or neurological pain and dysfunction.

Thanking you in advance for your assistance in this exciting field.

Andrew Bryson
Secretary
Australian Thermology Association
www.thermology.com.au

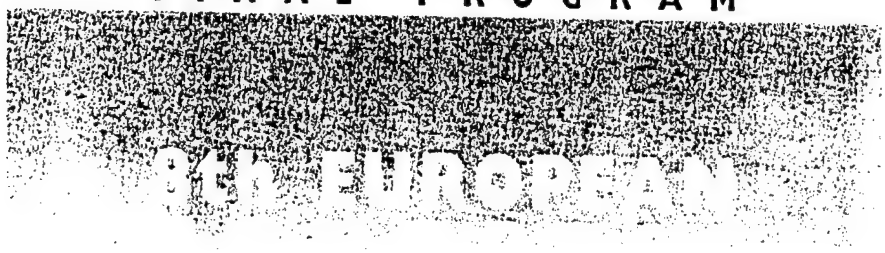
APPENDIX F

PAPER AND TRIP REPORT ITALIAN CONFERENCE

The European Association of Thermology

Associazione Italiana di Termologia

FINAL PROGRAM



3rd NATIONAL CONGRESS OF THE ITALIAN ASSOCIATION OF THERMOLOGY

Carzago di Calvagese
della Riviera (Brescia, Italy)
September 8-9, 2000

Palazzo Arzaga

Emerging Uncooled Infrared Technology

Nicholas A. Diakides
Advanced Concepts Analysis, Inc.
Falls Church, VA , USA

and

Raymond Balcerak
Defense Advanced Research Projects Agency
Arlington, VA , USA

ABSTRACT

A revolution is underway in infrared imaging technology. Many of the legacy systems, which incorporate cryogenically cooled linear arrays, mechanically scanned across the scene to form an image, can now be replaced by two dimensional detector arrays that do not require cryogenic cooling. This fundamental change in the design and operation of the imaging system has dramatically expanded the market and brought high quality thermal imaging within the grasp of the average consumer. Two noteworthy changes in system design form the underpinning of this new technology, providing the user with both improved performance and lower cost. These are the two-dimensional array or staring infrared technology, and the detector that operates without need for cryogenic cooling. The transition from scanning to staring infrared imaging initiates a major technology shift, with substantial impact on improved image quality, system simplicity, and cost reduction. The elimination of the cryogenics significantly reduces power and system cost. These factors lead to new applications, in both the commercial and military markets, with medical imaging being only one of the potential new applications. The improvements in image quality and cost reduction offered by the staring uncooled infrared technology have the potential to provide the physician a diagnostic aid, readily available at reasonable cost. This paper reviews the critical steps in development of this novel infrared imaging technology, and focuses on the status of the uncooled infrared cameras.

INTRODUCTION

As with the first generation of cameras, the next generation will also be proceeded by years of development, focussing on novel structures and improved materials, and leading to higher density pixel arrays with dramatically improved performance. The development leading to the next higher level of performance is underway. The focal plane goals are: 1) an increase in sensitivity to the theoretical limit, approximately 2 mK for the 50 x 50 micrometer pixel and 2) pixel size less than 25 x 25 micrometers. Noise mechanisms not evident in earlier development activities may dominate as the sensor technology approaches the radiation limit. The one-over-f noise, both in the detector and the read-out, can be a significant contribution to performance degradation. The instability in sensor characteristics caused by one-over-f noise provides an obstacle to further advances in camera technology, especially the ability to operate without temperature stabilization. All noise mechanisms in the detector and read-out must be meticulously characterized and understood in order reach the next level of performance. This begins with a thorough understanding of the current technology, both the camera and sensor characteristics.

1. IR Cameras and Focal Plane Arrays: Where we are today

Currently, uncooled focal plane array cameras are available from several sources. The focal plane sensors incorporate a detector operating as either a microbolometer or in the ferroelectric mode. The microbolometer materials are typically vanadium oxide or amorphous silicon, and a typical ferroelectric material is barium strontium titanate. The advertised, nominal sensitivity of the commercial camera system is 80 to 100 mK, but focal planes with considerably higher sensitivity are also routinely produced. The typical array size is 240x320 pixels, with 120x160 pixel arrays also available, primarily for miniature cameras. The pixel size in all the cameras is nominally 50x50 micrometers. The pixel size and array format produce excellent imaging for most commercial applications and for many of the military applications. The camera packages are similar to the visible cam-corders, with a weight of nominally 2 kilograms and power consumption of 5 to 10 watts.

2. Advances in Technology/Technical Issues

The uncooled infrared sensor technology continues to advance toward higher sensitivity, larger format arrays, and generally smaller, more compact cameras. Many of these advances depend upon pixel size reduction, accomplished without loss of sensitivity. Two generic pixel designs are currently under investigation: 1) single level structure; 2) multiple level structure. These are shown in Figure 1. Both pixel designs have the potential for significantly higher thermal sensitivity. The feasibility of the double-level structure has been demonstrated at Raytheon with a 50 mK sensitivity measured on a 240 x 320 camera with a 25 x 25 micrometer pixel. Experiments are underway to further improve sensitivity and to determine the sensitivity limits of this structure. The single level structure depends primarily upon innovation and advances in lithography to produce the thermal isolation support structure; while the multiple level design relies upon innovations in fabrication technology to produce structures with support legs beneath the pixel.

A comprehensive examination of the noise sources in advanced pixel structures is underway, with the objective of quantitatively assessing the sensitivity limits of the new pixel structures. The noise sources will be characterized as a function of pixel geometry, thickness, bias voltage, and contact geometry. These noise sources, including their relationship to the pixel structure and manufacturing processes, must be well understood in order to produce devices approaching the radiation-limited sensitivity. The noise analysis also leads to improved sensor stability over a wide range of ambient and background temperatures, which is essential to the realization of further advances in camera and signal processing technology. Technical efforts are being pursued simualtaneously in four critical areas, as shown in Figure 2, in order to achieve the desired technology enhancements.

3. Signal Processing Advances

Camera manufacturers have successfully applied unique sensor signal processing in several areas of uncooled infrared imaging. One of the most significant areas is the operation of the uncooled focal plane array (fpa) without thermoelectric stabilization. The thermoelectric stabilization maintains the focal plane at a uniform temperature, with well characterized off-set and gain coefficients. Operation without thermoelectric stabilization requires that the off-set and gain coefficients at each temperature be accurately characterized and stored in memory. The focal plane temperature is monitored and the correct set of coefficients applied, depending upon the fpa temperature. Although this seems a simple procedure, it is complicated by several factors: 1) the high degree of thermal sensitivity expected from the fpa; 2) non-linearity of the fpa as a function of temperature; 3) stability of the fpa as a function of time; 4) memory and signal processing requirements. Several camera manufacturers are addressing operation without temperature stabilization. As an example, data recently taken at Boeing demonstrated electronic stabilization over a temperature range of 15 C to 40 C, while maintaining a temperature sensitivity of 25 mK to

35 mK. Cameras operating over the full military temperature range are planned for evaluation in early 2001.

4. Major Application Categories

The potential for a robust commercial market sets the uncooled infrared apart from many other military imaging technologies. There is also some synergy between the desired characteristics of the military and commercial cameras.

There are numerous commercial applications of the uncooled infrared cameras, with several including the potential for relatively high volume. These can be grouped into four general categories, summarized in Table 1: 1) Security; 2) Driving and Navigation; 3) Surveillance; 4) Industrial process control. (Another potential category is Medicine as shown in Table 2.) The security market includes primarily police and fire-fighting. These are distinctly different applications, but with several common features. Low cost is of course paramount in most applications, but especially in the police and fire-fighting and medical market. The cost of the uncooled infrared camera often must be traded for other essential equipment. The focus on a light-weight, rugged, and user-friendly design presents unique challenges in these markets, which parallels the military requirement in many aspects. Also, the environment can be severe, especially in firefighting where the camera must not only operate at high ambient temperature, but also have the dynamic range to detect targets at high background temperature.

The driving and navigation applications are strongly driven by the automotive market, where again cost is paramount. The high volumes associated with this market are essential to meeting the cost goals, and a manufacturing infra-structure must be in place to produce cameras at a high production rate.

Surveillance sensors will be part of a sensor network, where imaging sensors will work in concert with other types of sensing. Since a large amount of data will be collected, the new challenges are signal processing to select the relevant information and integration of data from multiple sensors. Further, the same challenge will have to be addressed in the medical field where we will require multi-modality approaches and "smart" image processing.

Finally, the uncooled infrared offers increased reliability and significant cost reduction for industrial process control, where the sensors will be used for real-time monitoring of temperature sensitive processes.

5. SUMMARY

The uncooled infrared cameras have established a place among commercial camera technologies. Many of the infrared cameras are packaged in a configuration similar to commercial camcorders. High volume is on the horizon. Infrared cameras are entering the automobile market, and also finding application in police, fire-fighting and rescue, industrial process control and medical. Sensor technology development is underway to catapult the sensor and camera to another level of performance, equaling cooled sensors in many applications. The major challenges for wide acceptance of medical IR imaging are the following:
1) Better understanding of the pathophysiological basis of heat expressed on the surface
2) Standardization and quantification of clinical data
3) Databases (development of "smart" image processing)
4) Publications in leading journals

In summary, we advocate open colloquium and exchange of ideas at every conference where infrared is presented, collaborations among researchers, and the disseminating of well established work to other medical specialists (radiologists, heath care providers and government agencies,etc).

Figure and Table Captions

Figure 1

Microbolometer Pixel Structure - Reduction of the uncooled infrared pixel size has several benefits. The smaller pixel permits the use of smaller optics, increases the number of die per wafer, and provides the potential for improved resolution. These benefits are only obtained if sensitivity can be maintained constant as the pixel size is reduced. The two approaches to reduced pixel size are the single and the double level structure.

Figure 2

Building blocks for uncooled technology enhancements in four key areas.

Table 1

Applications of uncooled IR technology - major application categories.

Table 2

Applications of uncooled IR technology - medical applications and imaging methods.

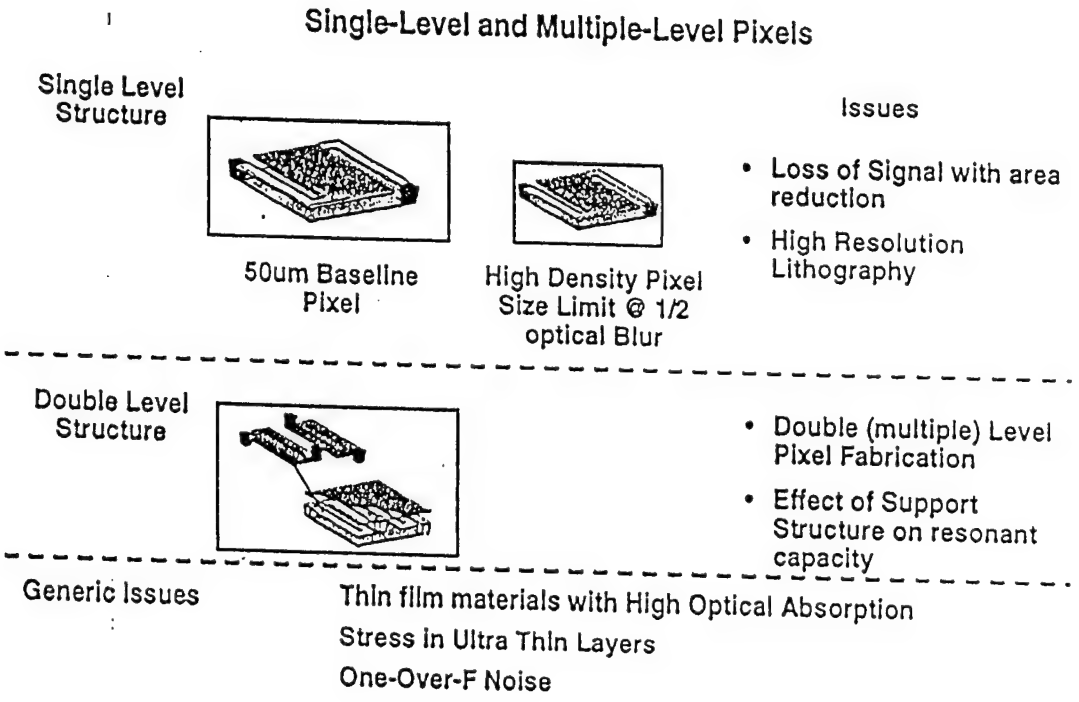


Figure 1

Microbolometer Pixel Structure - Reduction of the uncooled infrared pixel size has several benefits. The smaller pixel permits the use of smaller optics, increases the number of die per wafer, and provides the potential for improved resolution. These benefits are only obtained if sensitivity can be maintained constant as the pixel size is reduced. The two approaches to reduced pixel size are the single and the double level structure.

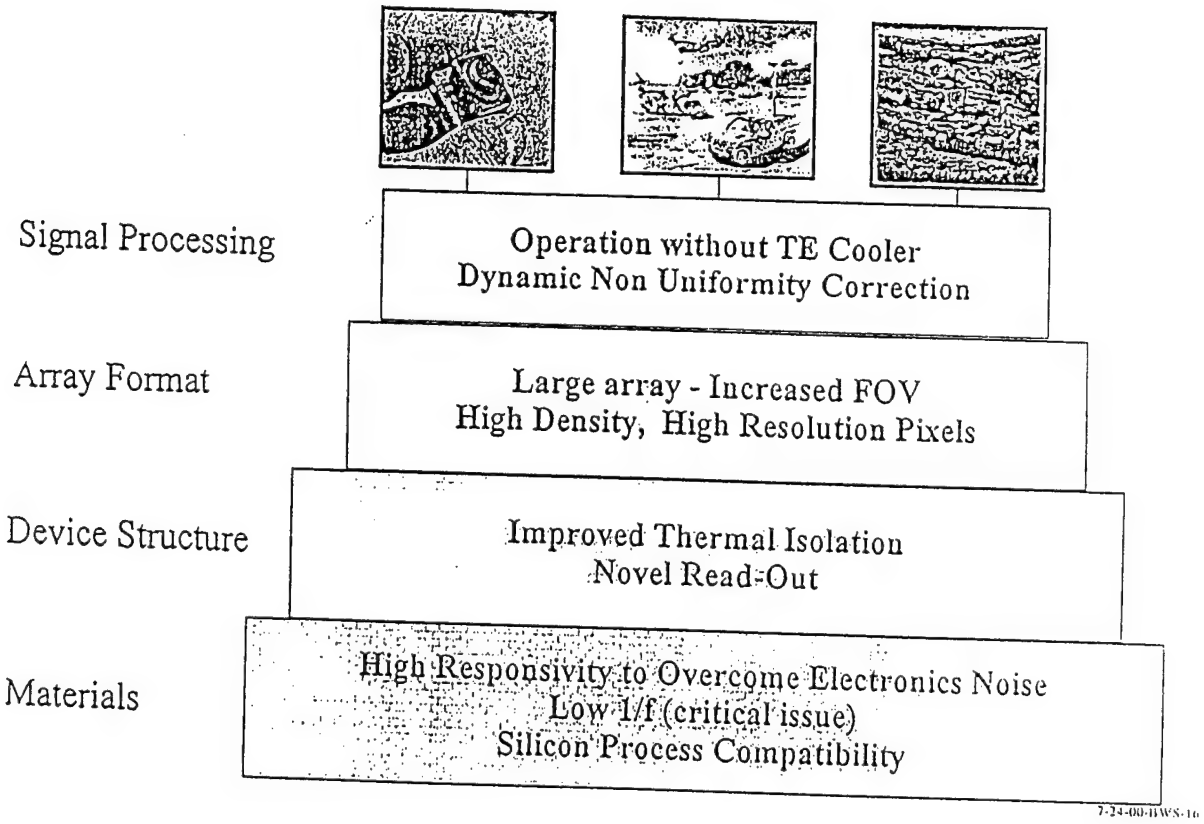


Figure 2

Building blocks for uncooled technology enhancements in four key areas.

Major Application Categories

Application	Major Features
Security Police Fire Fighting	Obscurant Penetration Light Weight; Rugged; Reliability; Low Cost
Driving and Navigation Automobile Boating	Extremely Low Cost
Surveillance Border Sentry Industrial Complex	Low False Alarm Rate Moderate Recognition Capibilty
Industrial Process Control	Temperature Measurement Processing Software

Table 1

Applications of uncooled IR technology - major application categories.

Medical Applications

Applications

- Oncology (breast, Skin, Etc.)
- Pain
- Vascular Disorders
- Arthritis/Rheumatism
- Neurology
- Surgery
- Telemedicine
- Tissue Viability (burns, etc.)
- Dermatological Disorders
- Monitoring Efficacy of Therapeutic Drugs, Etc.
- Neo-Natal
- Ophthalmology

IR Imaging Methods

- Static
- Dynamic (DAT, subtraction, etc.)
- Hyperspectral
- IR Tomography (slicing)
- Multi-Modality
- Sensor Fusion

Table 2

Applications of uncooled IR technology - medical applications and imaging methods.

TRIP REPORT
(Brescia, Italy, September 7 -9 , 2000)

TO: U.S. Army Research Office
ATTN: AMSSB-ACR (Melissa Fauber)
4300 South Miami Boulevard
Durham, NC 27709-2211

FROM: Nicholas A. Diakides
Advanced Concepts Analysis, Inc.
6353 Crosswoods Drive
Falls Church, VA 22044

Subject: Eighth European Congress of Medical Thermology, Brescia, Italy
Ref: DAAG55-98-C-0035

Date: September 28, 2000

Introduction:

At the invitation of Dr. Giorgio Dalla Volta, President of the European Congress of Medical Thermology, presented a paper "Emerging Uncooled Infrared Technology", N.A. Diakides and R. Balcerak, at this conference. This expanded on the latest uncooled technology developments by DARPA which have promising medical applications (a copy is attached). This paper will be published in the next issue of the Journal Thermology International.

Prior to the conference, met with the organizers of the European Congress and discussed key issues that still need to be established for the universal acceptance of Infrared Imaging in Medicine, and the continued collaboration in this work. This conference was well attended by scientists and physicians from all over the world (Japan, Korea, Australia, Latin America, Europe and U.S.A.). There were several representatives from Eastern European countries, such as Rumania, Hungary, Czechoslovakia. The Russians wrote papers and were expected , but were unable to attend due to some problems with the visas. The quality of papers surpassed our expectations, and we were impressed by the thoroughness of the work. A copy of the Final Program and a list of attendees is attached.

Discussion:

There was a significant amount of research work done which could be of interest to ARO. Some of this is as follows:

1) A paper presented by Professor Berz entitled " REGUVISION-Regulation Thermography by Thermal Imaging" dealt with the establishing of the parameter of health and mapping that and tracking any deviation from this as a potential sign for developing pathological processes. This method is ideal for detecting early deviations of the status of health , as well as controlling therapeutic interventions. Upon further discussions with the author, we ascertained that he is retained by Mercedes Benz/Chrysler Corporation for using this method for their workers and for developing an IR system for viewing the blind area behind trucks and for determining the mental alertness of the driver. (Please note that this information is proprietary at this time).

2) Dr. Dalla Volta, a neurologist who works in the area of pain, gave a paper "Headache: A Way to Test the Trigeminal Nervous System" which uses infrared imaging in order to differentiate migraine headaches where there is an asymmetrical thermal pattern in the patient's forehead from other types of headaches, such as a tension one, where the thermal pattern is symmetrical. He uses this regularly in his practice, as well as the IR monitoring of therapies. Further, in Trigeminal Neuralgia he uses thermography to distinguish between the primary and secondary form of the disease. The former results in a hot spot corresponding to the trigger zone (area of interest) and the latter displays a cold area in the cutaneous territory of the affected nerve ending.

3) Dr. Srini Govindan, a neurologist affiliated with Allegheny University, Pittsburgh, also uses IR imaging for pain management and headaches. He highlighted its clinical values in diagnosis and therapeutic monitoring.

4) Dr. Merla, University of Chieti, Italy, described his new technique based on Dynamic Digital Telethermometry. This method uses the functional information related to the local thermoregulatory process in order to detect and classify the stage of some pathological disorders. He uses thermal stress and records the changing dynamics of the thermal recovery curves in order to assess diseased as opposed to non-diseased areas. The results from these recovery curves ("tau" images) provide a wide range of information, which in the case of the clinical samples the researchers investigated, were closely confirmed by both ultrasound imaging and clinical examination. We also discussed his basic research work presented at the Chicago Conference last July on quantifying blood perfusion in micro-circulation. Since this research has potential use in military medicine, we recommend that it be included in the proposed ARO MURI Program.

5) Dr. Di Carlo, S. Gallicano Institute of Dermatology , Rome, gave a paper on "The Diagnostic Value of Thermography in Dermatology" highlighting its value in dermatological oncology. He uses infrared coupled with the "thermostimulation" method in order to increase the sensitivity of the measurement. In his work on melanomas and skin tumors, he found the presence of

the measurement. In his work on melanomas and skin tumors, he found the presence of hyperthermic halo with an elevated gradient whose edges extend well beyond the clinically evident lesion, and which is elliptical in shape, and extending toward the regional lymphocenters with a characteristic thermal flame morphology. This important "halo" effect recently has been observed by other investigators at Harvard Medical laboratories. In some cases, there are tumors that are not hyperthermic and those are mostly benign. He also presented a second paper "The Value of Infrared Thermography in the Study of Vasculopathies" showing that Thermography is rapidly becoming established in the vascular field by virtue of its ability to highlight the functional state of the skin's microcirculation He emphasized its importance in the clinical and experimental fields of determining the effects of vasoactive drugs and of the transcutaneous absorption of cosmetic products. He states also the importance of infrared imaging in the macrovascular field for the paraclinical examination of surface angiopathies (varicose veins, angiomas, etc.)

6) Dr. A. Jung, Military University School of Medicine, Warsaw, Poland, stated the advantages of infrared imaging as an effective, non-invasive method of measuring venous flow for diagnosis and detection of vascular diseases. She concludes that thermography allows the determining, with high accuracy, of limited or lack of vascular permeability (e.g. Thrombosis of venous vessels). She states that this technique is useful in monitoring therapeutics. In discussions with her, she expressed the interest of their military in medical infrared imaging.

7) Professor Mabuchi, University of Tokyo, presented an excellent paper on "Evaluation of Rapidly Changing Thermal Phenomena in the Living Body through Image-Processing of a High-Speed Far-Infrared Camera". For the visualization of the changing thermal phenomena in the body, he developed a program for a computerized high-speed infrared thermal imaging system that can produce dynamic imaging with respect to skin blood flow or the function of the autonomic nervous system. In order to evaluate the dynamic change in the distribution of skin temperature caused by the stimulation, a time-series of subtraction images was then calculated by subtracting a control image (taken before the stimulation) from each of the original time sequential images, and after being processed by temporal smoothing and spatial filtering. This time series of subtraction images were displayed dynamically using either a three-dimensional display method or a conventional two-dimensional one. These results suggest that physiological functions of the living body (circulatory system, autonomic nervous system, etc.) and abnormalities represented by rapid changing thermal phenomena could be evaluated using this technique.

8) Professor Michael Anbar, State University of New York in Buffalo, presented a paper entitled "Effect of Cancer on the Dynamics of Autonomically Controlled Cutaneous Microcirculation", in which he talks about the effect of Nitric Oxide on the cutaneous perfusion controlled by the autonomic nervous system. He uses an innovative method developed by him called Dynamic Area Telethermometry (DAT) to dynamically capture the attenuation of modulation of perfusion and consequently the temperature. The latter has been demonstrated in limited clinical studies which revealed sensitivity in cancer detection greater than 93% and a specificity of 93%. This dynamic gathering of images uses fast Furier transform analysis of temperature modulation and

prostate. This is very promising preliminary work.

9) Professor Iwao Fujimasa, National Graduate Institute for Policy Studies (GRIPS), Tokyo, Japan, presented a paper entitled "Clinical Trials of Thermal Coronary Angiography System". It contained the results of the clinical trials in the area of coronary surgery. The system consists of sensor fusion of an infrared camera boresighted with a video (visible) camera. This was used for a pilot study on three patients who underwent bypass surgery. This is the first time that such a system has been used for this application. The authors presented a detailed description of their system and defined design requirements and specifications. The clinical validation is continuing.

Conclusion:

There is a trend to add dynamic methods to the static imaging in order to enhance the diagnostic capability of infrared. This may be something to consider seriously for some studies which can quantify the efficacy of this addition. This could be part of the ARO proposed MURI program.

The work on blood perfusion and microcirculation is being carried out in several universities and institutes and has great potential for military application in combat casualty care.

There are several papers outlined here (we could not include all of them) which show new initiatives. The one dealing with the assessment of human alertness in certain instances is of direct interest to General Parker , Commander, MRMC, for soldier performance (sleep deprivation, alertness, etc.). Another area of military interest is pain management and the establishing of measures of wellness, etc. as shown in the above discussion.

There is undoubtedly a tremendously increased interest in the clinical use of infrared imaging as witnessed by the quality and number of papers and new work presented . Furthermore, the presence of a major camera manufacturer (FLIR) and some international pharmaceutical companies (GLAXO, MERCK, PFIZER, etc.) attests to the possible beginning of industry involvement in this area.

In summary, the exposure of medical IR through conferences and publications has greatly contributed to the expansion of infrared imaging research, clinical quantification and collaborations. The work sponsored by this contract has played a significant role in this area, not only in the United States but also worldwide.

Elenco partecipanti al convegno

Categorie: Tutte
Stato iscrizione: Qualunque

Nr.	Cognome e Nome	Ente	Indirizzo		categ. / stato iscr.
1	Dott. Ammer Kurt	LBF fuer Physikalische Diagnostik	Heinrich Collinstrasse 30 A-2240 Vienna	Austria	Ospite Iscritto
2	Dr. Anbar Michael	University of Buffalo School of Medicine and Biomedical Departments of Physiology & Biophysics and Surgery	14214 Buffalo (NY)	USA	Moderatore Iscritto
3	Prof. Benko Imre	Thecnical University of Budapest Department of Energy	Muegyetem rkp. 7/D.208 H 1521 Budapest	Hungary	Iscritto Iscritto
4	Dr. Berz Reinhold	EvoBus GmbH Setra Omnibusse	Kaessobohrerstrabe 13 89077 Ulm	Germany	Moderatore Iscritto
5	Dott.ssa Bettaglio Raffaella	Fondazione Maugeri Unità di Cure Palliative e Terapia del Dolore	Via Ferrata 8 27100 Pavia (PV)	Italia	Ospite Iscritto
6	Dott. Bonetti Matteo				Ospite Iscritto
7	Dr. Bonezzi Cesare	Fondazione Maugeri	Via Ferrata 8 27100 Pavia (PV)	Italia	Ospite Iscritto
8	Dott.ssa Boyd Alexandra			Australia	Iscritto Iscritto
9	Dr. Brioschi Marcos L.	Thermotronics	R Ver Augusto Staben 46 Bacacheri 82515 Curitiba 240 Parana	Brazil	Iscritto Iscritto
10	Dr. Camaioni Domenico	Complesso Integrato Columbus	Via G. Moscati 31 00168 Roma (RM)	Italia	Ospite Iscritto
11	~~Dott Shitt~~	Studio Ecografico Dr. S. Ciatti	Via S. Giorgio 13 50047 Prato	Italy	Iscritto Iscritto
12	Dr. Cho Yong-Eun	Yongdong Severance Hospital Yonsei University College of Medicine - Dept. of Neurosurgery	Young Dong, P.O. Box 1217 Seoul	Korea	Ospite Iscritto
13	Dr. Ciatti Stefano	Studio Ecografico Dr. S. Ciatti	Via S. Giorgio 13 50047 Prato	Italy	Ospite Iscritto
14	Dott. Dalla Volta Giorgio				Iscritto Iscritto
15	Dr. Di Carlo Aldo	Istituto Ospedaliero Dermosifilop. di S. Maria e S. Gallica	Via S. Gallicano 25/A 00153 ROMA (RM)	Italy	Ospite Iscritto
16	Dott.ssa Diakides Mary	Advanced Concepts Analysis Inc.	6353 Crosswoods Drive 22044 Falls Church (VA)	U.S.A.	Iscritto Iscritto
17	Dr. Diakides Nicholas	Advanced Concepts Analysis Inc.	6353 Crosswoods Drive 22044 Falls Church (VA)	U.S.A.	Iscritto Iscritto
18	Dott. Evangelista Maurizio				Ospite Iscritto
19	Prof. Fujimasa Iwao	National Graduate Institute for Policy Studies (GRIPS)	2-2 Wakamatsu-cyo, Shinjyuku-ku Tokyo 162-8677	Japan	Moderatore Iscritto

Nr.	Cognome e Nome	Ente	Indirizzo		categ. / stato iscr.
20	Dr. Govindan Srini	Institute of Disability Medicine Inc.	40 Madical Park, suite 304 WV 26003-6389 Wheeling	U.S.A.	Ospite Iscritto
21	Dott. Grinzato Ermanno				Iscritto Iscritto
22	Dr. Harding John R.	St. Woolos Hospital X-Ray Dept.	Crdiff Road NP202 Newport, Soth Wales	United Kingdo	Iscritto Iscritto
23	Dr. Howell Kevin J.	Royal Fee Hospital Centre for Rheumatology, Royal Free Campus	Rowland Hill Street NW3 2 London	UK	Iscritto Iscritto
24	Prof. Jones Bryan	University of Glamorgan School of Computing	CF371 Pontypridd	UK	Iscritto Iscritto
25	Dott.ssa Jung Anna	Central Clinical Hospital Pediatric Clinic	Szasevow 128 str. 00-909 Warsaw	Poland	Moderatore Iscritto
26	Dr. Kang Ho-Yeong	Wooridul Hospital	47 4 Chungdam Dong, Kangnam Gu Seoul 135-10 Seoul	Korea	Iscritto Iscritto
27	Dr. Kanie Ryoichi	Nagoya City University Medical School Deparment of Orthopaedic Surgery and Rehabilitation Medicine	Mizuho-cho, Mizuho-ku 46700 Nagoya	Japan	Iscritto Iscritto
28	Dr. Mabuchi Kunihiko	University of Tokyo Center for Collaborative Research	4-6-1, Komaba, Meguro-ku 15389 Tokyo	Japan	Iscritto Iscritto
29	Dr. Maca Thomas	General Hospital and Univ. Of Vienna Dpt. Medical Angiology	Waehringer Guertel 18-20 1097 Vienna (A)	Austria	Iscritto Iscritto
30	Dott. Maiorana Maurizio				Iscritto Iscritto
31	Dott. Mayr Hans	Institute fur RPMR v. Rheumatologie Ka Sanatorium Mera	1090 Vienna	Austria	Iscritto Iscritto
32	Dott. Merla Arcangelo	Università degli Studi di Chieti Istituto di Tecnologie Avanzate Biomediche	Via dei Vestini 33 66013 Chieti (CH)	Italia	Iscritto Iscritto
33	Dott. Miranda Calderin Guillermo	Instituto Canario de Ciencias Neurologicas c/ Mendez y Pelayo 8	35010 Las Palmas de Gran Canaria	Spain	Iscritto Iscritto
34	Dott. Musiari Giorgio				Iscritto Iscritto
35	Dott. Nattero Giovanni		Strada Campagnino, 46 10133 Torino (To)	Italia	Iscritto Iscritto
36	Dr. Orlandini Guido	Ospedale di Tortona Servizio di Terapia del Dolore	Piazza F. Cavallotti 7 15057 Tortona (AL)	Italy	Ospite Iscritto
37	Dr. Pari Gilberto	Media Express	Via Italia 29 47900 Rimini (Rn)	Italy	Ospite Iscritto
38	Dr. Pascoe David D.	Auburn University Department of Health and Human Performance	20580 Memorial Coliseum 36849 Auburn (AL)	USA	Iscritto Iscritto
39	Dr. Prastowski Adam	Medical Academy in Wroclaw Clinic and Department of the Orthopedy		Poland	Iscritto Iscritto

Nr.	Cognome e Nome	Ente	Indirizzo		categ. / stato iscr.
40	~~Dr. Prilutchi Mark~~	Union of Western and Oriental Medicine	Gagarin Ave.,23/1 60302 Nizhni Novgorod	Russia	Iscritto Iscritto
41	Dr. Purohit R.C.	Auburn University Department of Large Animal Surgery and Medicine	36849 Auburn (AL)	USA	Iscritto Iscritto
42	Prof. Ring Francis J.	Royal National Hospital for Rheumatic Diseases	BAI IR Bath	UK	Ospite Iscritto
43	Dr. Rodan Gheorghe	National Institute for Aerospace Research	Bd.Iuliu Maniu, 220 sect.6 77538 Bucharest	Romania	Iscritto Iscritto
44	Dott. Yeler Abdulkadir	Aselsan		Turkey	Iscritto Iscritto
45	Dr. Zuber Janusz	Central Clinical Hospital Pediatric Clinic	Szasevow 128 str. 00-909 Warsaw	Poland	Iscritto Iscritto

APPENDIX G

ABSTRACTS OF PAPERS IN MEDICAL IR IMAGING FROM PROCEEDINGS OF THE IEEE/EMBS INTERNATIONAL CONFERENCES (1998-2000)

Final Program and Abstract Book of 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society

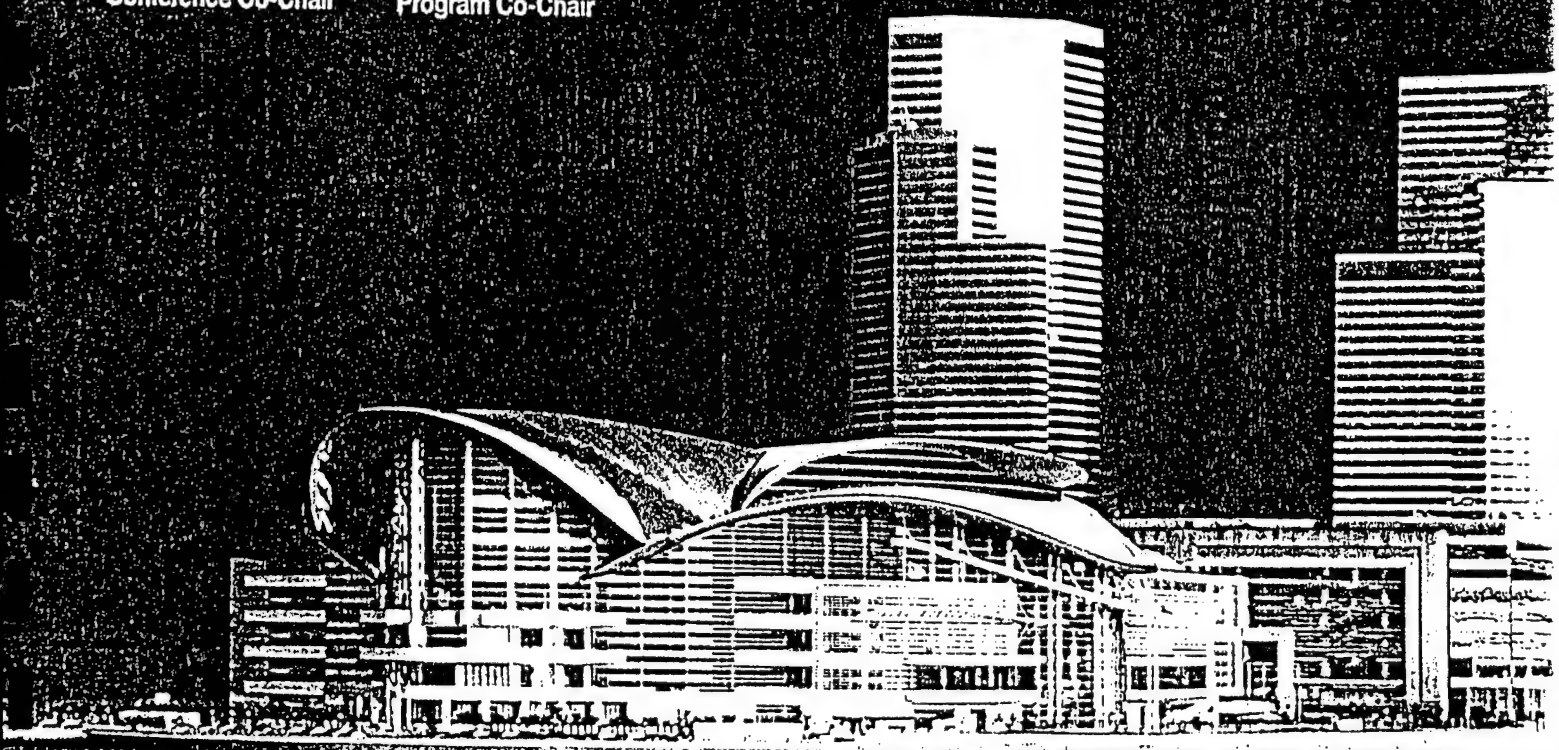
"Biomedical Engineering Towards The Year 2000 and Beyond"

H.K. Chang
Conference Chair

Y.T. Zhang
Program Chair

Andrew Szeto
Conference Co-Chair

Rangaraj M. Rangayyan
Program Co-Chair



29 October to 1 November, 1998

The Hong Kong Convention and Exhibition Centre

IEEE

EMB

unknown. Comparisons of this novel method with single adaptive weighted mean filtering or the multiscale soft thresholding method are also presented in the paper.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-854, 1998

2.5.4-6 Oct. 31 SAT 14:30 - 16:00 Rm301 782
An Automatic 3D Surface Extraction in Ultrasonic Images

Hao XH, Gao SK, Gao XR, Xin Y, Zhang TH, Tsinghua University , China
Email:gsk-dea@mail.tsinghua.edu.cn

This paper presents an automatic 3D surface extraction method for ultrasonic images. In this technique, image sequence is obtained along one axis of the 3D grid data. Based on the space continuity of the object, the region of interest (ROI) in each frame is determined by using a novel Polygon-based Tracking (PT) method. The edge in ROI is then automatically extracted by region growing technique, whose character vector is linearly constructed by the pixel value and the local entropy. Finally, the 3D surface is formed by recombination of the edges in 2D image sequence. Experiments on a water bubble ultrasonic images show that the new method is successful in detection of 3D surfaces.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-857, 1998

2.5.5 Ultrasound Image and Tissue Analysis

2.5.5-1 Oct. 31 SAT 14:30 - 16:00 Rm301 236
Elasticity Imaging of Artery Walls with Intravascular Ultrasound

Wan MX, Li YM, Li JB, Cui YY, Xi'an Jiaotong University, China
Email:mxwan@xjtu.edu.cn

Intravascular ultrasound (IVUS) techniques offering grayscale images of artery with sub-millimeter resolution, are the basis of imaging artery elasticity. we approached rectifying method to transducer off-axis effect and optical flow estimation method based on genetic algorithm (GAOF) for the estimation of the strain in artery wall. Furthermore, elasticity profile reconstruction is performed using the strain and equilibrium equations. Combining these methods and carefully operating, the results in vitro demonstrate that elasticity imaging of artery with sub-millimeter resolution is possible.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-860, 1998

2.5.5-2 Oct. 31 SAT 14:30 - 16:00 Rm301 258
Ultrasonic Parameters of Renal Calculi

Singh VR, Singh S, National Physical Lab., India
Email:vrs@csnpl.ren.nic.in

Ultrasonic parameters such as ultrasonic velocity, acoustic impedance, attenuation, dynamic modules of elasticity, coefficient of reflectance and transmittance have been determined for several renal calculi samples, in vitro. These parameters are studied by using a single probe method (pulse echo) in liquid form at different concentration (gm/cc). It was found that as the concentration increases, the ultrasonic velocity increases. A pulse receiver (model Panametries-5052 PR) was used to excite the transducer (2.5 MHz) and the output was given to CRO (model-0S-300C, 20MHz). A sample holder assembly was used in the present work. We have also determined all acoustic parameter mentioned above by using a double-probe through-transmission method for several renal calculi samples in the solid rock form. The present study would help in determining the design parameters to design and develop a simple kidney stone lithotripter.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-862, 1998

2.5.5-3 Oct. 31 SAT 14:30 - 16:00 Rm301 666
Peak Position Estimation Algorithms for Cross-Correlation Function in Elastography

Ding CX, Bai J, Tsinghua University, China
Email:dcx@bmel.eea.tsginhua.edu.cn

In ultrasound Elastography, the resolution and accuracy of strain estimation are bounded by the sampling period when the echo signal is digitized. In this paper, we describe three new algorithms which based on multi-resolution, time-shift property of Fourier Transform and sinc function interpolation, respectively, for improving the precision of peak position estimation of cross-correlation function between echo signals obtained pre- and post- target tissue compression. Experimental results demonstrate that these methods bring about good effects.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-866, 1998

2.5.5-4 Oct. 31 SAT 14:30 - 16:00 Rm301 839
Automatic Detection of Fetal Movement Using M-Mode Ultrasonography

Kwon JH, Kang DJ, Lee DH, Park MI, Kim SI, Hanyang Uni., Korea
Email:spallow@unitel.co.kr

In this paper, we propose an algorithm to detect fetal movements using M-mode ultrasonography. To do this work automatically, we find the crosscorrelation between the current data vector of the depth direction of M-mode image and the previous one. In the crosscorrelation estimator, the variations of time lag tau at maximum crosscorrelation value means fetal movements. A woman in the 37th week of pregnancy was monitored and the ultrasonic image of fetus was recorded over 20-minute period to detect fetal movements using B-mode and M-mode ultrasonography simultaneously. And the presented method was compared with maternal perception and B-mode ultrasonography observed by clinician. The maternal perception method detected only 57% of all fetal movements observed by clinician. The detection of the presented method corresponds to the clinician's detection result.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-869, 1998

2.5.5-5 Oct. 31 SAT 14:30 - 16:00 Rm301 1034
Automatic Recognition of Malignant Lesions in Ultrasound Images by Artificial Neural Networks

Ruggiero C, Bagnoli F, Sacile R, Calabrese M, Rescinito G, Sardanelli F, Dist - University of Genova, Italy Email:carmel@dist.unige.it

A method for the automatic classification of lesions in ultrasound images by artificial neural nets is presented. The parameters used for training of the network are texture related indicators and shape related indicators. Three lesions have been considered: cysts, fibroadenomas and carcinomas. Solid lesions have been separated from cysts in the first step and carcinomas have been separated from fibroadenomas in a second step. A satisfactory classification between cysts and solid lesion can be achieved using texture parameters only, whereas shape parameters appear to be the most significant ones when classifying between carcinomas and fibroadenomas.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-872, 1998

2.6.1 Optical Imaging I

Session Chair: Joseph Schmitt,Hong Kong University of Science and Technology,Hong Kong SAR

Session Co-Chair: Andreas Hielscher,State University of New York,USA

2.6.1-1 Oct. 29 THU 10:30 - 10:45 Rm204/205 690
Image Reconstruction Schemes for Optical Tomography

Hielscher AH, Klose A, State University of New York, USA
Email:ahielscher@netmail.hscbklyn.edu

We have developed a novel approach to the image reconstruction problem in optical tomography. Unlike currently available schemes, this method does not assume that the solution is a small perturbation to a known reference medium. In our approach the reconstruction problem is viewed as an optimization problem, which can be solved by gradient-based optimization techniques.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-876, 1998

2.6.1-2 Oct. 29 THU 10:45 - 11:00 Rm204/205 160
Experimental Study on Localization of Absorbers Within Tissue Phantom Using A Simple Phased-Array System

Lin F, Su C, Ding HS, Wang GZ, Zhou XQ, Zhang YH, Bai J, Britton C, Tsinghua University, China Email:linfang@hmi.eea.tsinghua.edu.cn

A simple phased-array system with two anti-phased near infrared (NIR) light sources whose intensities are modulated sinusoidally at 200MHzis established, and experiments for exploring the light distribution in homogeneous tissue phantom (0.25% intralipid) and the perturbations of intensity null and phase transition by absorbers are carried out. Experimental results in this paper show regular light intensity null and sharp phase transition of 180° at the mid-line of the two sources, conform closely with the prediction by diffusion theory and the results of other groups[1,2]. Our measurements clearly demonstrate the distortion of the light distribution by the existence of absorbers and the effects on the perturbations caused by different sizes and locations of the objects. The effect on the objects resolution of the spacing of the two light sources is also investigated and we found that higher resolution may be achieved by narrower spacing. Particularly, we have studied the possibility of distinguishing between two absorbers and have given initial results. It is concluded that phased-array system could be simple, feasible, and effective for small absorber discrimination in otherwise homogenous body tissues.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-880, 1998

2.6.1-3 Oct. 29 THU 11:00 - 11:15 Rm204/205 442
Development of Depth Extraction Algorithm for the Stereo Endoscopic Image

Kim JH, Hwang D, Jeong HK, Song CG, Lee KS, Lee MH, Yonsei University, South Korea Email:draus@unitel.co.kr

This paper presents the development of depth extraction algorithm for the stereoscopic Endoscope data using a stereo matching method. Generally, the purpose of existing stereo algorithms is to reconstruct stereo object surface and depth map. But the main purpose of our processing is to give exact depth feeling to doctor showing depth information in some points. For this purpose, this paper presents two stereo matching algorithms which are to measure exact depth. One is variable window - based algorithm, and the other is reference points - based algorithm for a fast processing.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-884, 1998

2.6.1-4 Oct. 29 THU 11:15 - 11:30 Rm204/205 509
Sonoluminescent Tomography

Wang LH, Shen QM, Texas A&M University, USA

Email:LWang@tamu.edu

A novel optical imaging technique called sonoluminescent tomography (SLT) was developed for cross-sectional imaging of strongly scattering media noninvasively. Sonoluminescence, which was generated internally in the medium by continuous-wave ultrasound, was used to produce a two-dimensional image of an object embedded in a scattering medium by raster scanning the medium. The image had a high contrast and good spatial resolution. The spatial resolution was limited by the focal spot size of the ultrasound and can be improved by tightening the focus. This inexpensive imaging technique has potential applications in medicine and other fields related to scattering media.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-888, 1998

2.6.1-5 Oct. 29 THU 11:30 - 11:45 Rm204/205 111

Adaptive Beamforming for Optical Coherence Tomography of Biological Tissues

Yung KM, Xiang SH, Schmitt JM, Hong Kong SAR
Email:eekinman@ee.ust.hk

Coherent noise in images of highly scattering tissues acquired by optical coherence tomography (OCT) reduces the visibility of microscopic features. Incoherent summation of interference signals from multiple array elements has been shown previously to improve the signal-to-noise ratio of OCT images at the expense of resolution loss. This study demonstrates the improvement in image quality that can be achieved without loss of resolution by applying adaptive beam-forming techniques. We built and tested a prototype four-detector OCT scanner and tested it performance on particle-in-gelatin phantoms and living tissue.The weighting vector applied to the array signals before summation was calculated from the inverse of the 4x4 convariance matrix measured for each A-line. Compared to the images formed from the single-channel and coherently added signals, the processed images were found to be substantially sharper and less noisy.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-891, 1998

2.6.1-6 Oct. 29 THU 11:45 - 12:00 Rm204/205 870

Intestinal Abnormality Detection From Endoscopic Images

Krishnan SM, Yang X, Chan KL, Kumar S, Goh PMY, Nanyang Technological University, Singapore Email:esmkrish@ntu.edu.sg

A method for the detecting the possible presence of abnormality during the endoscopy of the lower gastro-intestinal system is presented. Image contours corresponding to haustra creases in the colon are extracted and curvature of each contour is computed after non-parametric smoothing. Zero-crossings of curvature along the contour are then detected. The presence of abnormality is identified when there is a contour segment between two zero-crossings having the opposite curvature signs to those of the two neighboring contour segments. Results show that the proposed method for detecting the possible presence of abnormality such as polyps and tumors is feasible.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-895, 1998

2.6.2 Optical Imaging II

Session Chair: Andreas Hielscher,State University of New York,USA

Session Co-Chair: Lihong Wang,Texas A&M University,USA

2.6.2-1 Oct. 29 THU 16:30 - 16:45 Rm204/205 853

Dependence of Time and Space Resolved Reflectance on the Particles Size Distribution Near the Tissue Surface

Avrillier S, Tualle JM, Tinet E, Gelebart B, Universite Paris-XIII, France
Email:arriller@gafifee.iuniv-paris 12.fr

We have performed experiments to explore the time and space resolved reflectance obtained from aqueous solutions of calibrated latexmicrospheres very close to the illumination point. The experimental set-up consists of a titanium-sapphire pulsed laser and a streak camera. The size distribution of the latex spheres was varied in order to obtain : 1) various anisotropy factors g with a Mie phase function, 2) various phase functions at a given g.The experimental results at early times and close to the light source have been compared to Monte-Carlo numerical simulations. We have deduced some rules to obtain the g value of turbid media by analyzing the backscattered light and we have demonstrated that time and space resolved reflectance could be dependent on the shape of the phase function.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-899, 1998

2.6.2-2 Oct. 29 THU 16:45 - 17:00 Rm204/205 539

Near Infrared Spectroscopy (NIRS) During Papaverine Therapy and Balloon Occlusion Angiography: Case Reports

Martinez-Coll A, Morgan MK, Nguyen H, Hunyor SN, Australia
Email:fredo@med.usyd.edu.au

NIRS allows non-invasive measurements of relative blood volume and oxygen saturation in various tissues. One of its most important applications is in neurosurgery and neurointensive care, monitoring changes in perfusion and oxygen utilization in the brain. The following report describes two separate clinical cases: one during progressive intraarterial papaverine therapy in cerebral vasospasm, and the other during balloon occlusion angiography. A 30-mW variable gain, dual wavelength (769 nm, and 850 nm) NIRS instrument with a 5 mm^2 photon detector was used. The NIRS probe was positioned on the ipsilateral temporal and frontal regions for papaverine therapy and balloon occlusion, respectively. Changes in tissue oxygen saturation (DESAT) and blood volume (BV) were acquired continuously during progressive injection of intraarterial papaverine, as well as during 20 minutes of balloon occlusion. During papaverine therapy there were systematic statistically significant decreases in DESAT ($p < 0.001$) for all incremental doses of papaverine; as well as between pre-occlusion (baseline), at 10 min and 20 min of occlusion, and after release of occlusion,: ($p=<.0001$). BV changes where significant between baseline and 20 min of occlusion and between 10 and 20 min of occlusion.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-902, 1998

2.6.2-3 Oct. 29 THU 17:00 - 17:15 Rm204/205 533

Development of An Optical System for the Detection of Oral Cancer Using Near-Infrared Spectroscopy

Cooney KM, Gossage KW, McShane MJ, van der Breggen EWJ, Motamedi M, Coté GL, Texas A&M University, USA Email:kmc8646@acs.tamu.edu

A system was developed using a Fourier Transform spectrometer to investigate spectral differences between malignant, benign and healthy oral tissue in the near-infrared range (2.0-2.5 microns). A hamster model for oral squamous cell carcinoma and one for benign lesions in soft oral tissue (i.e. inflammation) was used. After tissue transformation in the malignant and benign cases and when no transformation occurred (i.e. healthy), the animals were euthanized and the cancerous as well as the normal tissue were excised. Infrared absorption spectra of the buccal mucosa were then collected on all three models, in vitro. A total of 160 near-infrared (NIR) scans were taken, 70 on malignant tissue, 20 on benign, inflamed, tissue and 70 on healthy tissue. Multiplicative signal correction (MSC), used during preprocessing, together with principal component analysis (PCA) showed a 90% sensitivity, 87% specificity and a false negative rate of .10 between malignant and healthy/benign tissue types across animals using this wavelength range. The results of the PCA analysis indicated that differences were detectable in the 2.25-2.35 µm range. Absorption bands in this range are due to the N-H stretching, C=O stretching vibration, and C-H deformation vibrations.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-906, 1998

2.6.2-4 Oct. 29 THU 17:15 - 17:30 Rm204/205 927

Novel Microscopy System for Imaging Brain Tissue Structure and Function

Lee J, Chung W, Hanley D, Thakor NV, Johns Hopkins University School of Medicine, USA Email:ljohnson@bme.jhu.edu

We developed a novel microscope system to image changes in light scatter that occur within a hippocampal slice. The system is based on Mie scatter theory predictions for light scatter as well as empirical observations. We evaluated the imaging system with two types of samples, a thin layer of microspheres, radius 450nm, suspended in water and a brain tissue slice. The variation of the dilution of the microspheres revealed two regimes in which the system responds differently. We believe the transition from one regime to the other occurs when single scatter begins to dominate. We also tested the system on 350 micron thick hippocampal slices. We detected increases in light scatter of up to 50% in 100 µM NMDA treated slices. Thus, optical scatter imaging captures changes in brain tissue morphology that occur with brain injury.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-910, 1998

2.6.2-5 Oct. 29 THU 17:30 - 17:45 Rm204/205 555

The Automatic Image Analysis of Red Blood Cell Deformability and Blood Flow in Microchannels with An Image-Intensified High-Speed Video Camera System

Shimizu T, Sekizuka E, Oshio C, Tsukada K, Nagai T, Hokari R, Minamitani H, Keio University, Japan Email:shimizu@bmel.elec.keio.ac.jp

It is crucial in microcirculatory investigation to evaluate red blood cell (RBC) deformability. However, there are almost limited information and indirect method of analyses. We tried to measure RBC deformability automatically by a combination of a newly developed algorithm and recording of individual RBC images clearly with an image-intensified high-speed video camera system. The length and the diameter of individual RBCs were measured automatically for RBC velocity measurement. RBC deformability was calculated from the histogram of density at each pixel by our algorithm. To ensure reliability of this system we compared actual measurement with automatic analysis for RBC velocity and RBC deformability. Each correlation value (R^2=0.99) showedthe validity of this system. In addition this system can shorten the time needed for measuring.

We could confirm that the deformability of diabetic RBCs of HbA1c 12.1% was much more decreased compared with that of Hba1c 6.4%. The deformability of diabetic RBCs might depend on hyperglycemic degree of diabetic patients. In addition, the pentoxifylline improved the deformability of diabetic RBCs.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-914, 1998

2.6.3 Infrared Imaging I

Session Chair: Iwao Fujimasa,National Graduate Institue for Policy Studies,Japan

Session Co-Chair: Jenny Freeman,HypesMed Imaging, Inc.,USA

2.6.3-1 Oct. 31 SAT 8:30 - 8:45 Rm207/208 616
Infrared Imaging in Diabetic Foot Ulceration

Harding JR, Wertheim DF, Williams RJ, Melhuish JM, Banerjee D, Harding KG, St. Woolos Hosptial, UK Email:hardxrag@gwent.nhs.gov.uk

Diabetic foot ulcers present a difficult problem in clinical management because of increased risk of soft-tissue infection in diabetes plus impaired local blood supply due to diabetic vascular disease. Infection of diabetic foot ulcers has particular risk of involvement of the adjacent bone resulting in the serious complication of osteomyelitis. This needs early aggressive antibiotic therapy to avoid even more serious secondary long-term complications, but unfortunately clinical diagnosis and radiological examination may be unhelpful in early osteomyelitis, when antibiotic therapy is most effective. Furthermore the large number of patients plus the chronic nature of diabetic foot ulceration precludes routine investigation for early osteomyelitisby X-ray or isotope bone scanning in every case, for logistic, radiation protection, and cost reasons. This preliminary study has shown significantly increased temperature on infrared imaging, not only around the ulcer, but in the entire foot in patients subsequently confirmed radiologically as having earl yosteomyelitis.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-916, 1998

2.6.3-2 Oct. 31 SAT 8:45 - 9:00 Rm207/208 915
Computerized Thermal Breast Imaging Revisited: An Adjunctive Tool to Mammography

Parisky YR, Skinner KA, Cothren R, DeWittey RL, Birbeck JS, Conti PS, Rich JK, Dougherty WR, USC/Norris Comprehensive Cancer Hospital, USA Email:yparisky@hsc.usc.edu

Physical examination and mammography are the primary methods for the detection of breast cancer, but lead to a high rate of benign biopsies. A digital thermal imaging system was developed as an adjunct to mammography to aid in the differentiation of benign from malignant lesions.

Patients scheduled for biopsy were enrolled after informed consent. Prior to biopsy, digital thermal images were acquired of each breast during a 3.5 minute procedure. A probability of malignancy was assigned to each pixel, based on comparative statistical analysis of the thermal response features from the test subjects with data derived from lesions of known pathology. One hundred and seventeen female patients (125 suspicious lesions) were included, with a 24% true malignancy rate. Receiver Operating Characteristics (ROC) curves (Sensitivity vs. 1-Specificity) were generated based on various features of the cooling model. Based on the ROC curve analysis, 36/95 benign biopsies (38%) could have been avoided using this technology, while maintaining a sensitivity of 96%.

Digital thermal imaging appears to be a valuable adjunct to mammography in the management of breast lesions, potentially decreasing the number of benign biopsies. Multi-institutional FDA clinical trials are currently underway.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-919, 1998

2.6.3-3 Oct. 31 SAT 9:00 - 9:15 Rm207/208 118
A Study on Abdominal Temperature of Dysmenorrhea Patients

Lee KS, Cho JH, Kyung Hee University, South Korea Email:Kyungsl@unitel.co.kr

Dysmenorrhea is one of the common gynecologic disorders of menstruating women. Primary is menstrual pain without pelvic pathology, whereas secondary is painful menstruation with underlying pathology. The cause of primary is increased endometrial prostaglandin. The mechanisms underlying secondary dysmenorrhea are not elucidated.

There are many blood vessels under the skin and they play a very important role on the thermal control of peripheral part. The control of blood circulation is mainly controlled by autonomic nervous system and it is known that D.I.T.I. is an objective method showing the body temperature.

In oriental medicine, the causes of dysmenorrhea have been recognized as something not to be penetrated such as qi, blood, and pathologic factors. These conditions can inhibit the circulation of Chong Ren Channel.

We observed the 49 patients complaining of dysmenorrhea who visited our hospital during 1997. In order to rule out the thermal abnormality due to obesity, we used obesity index and excluded the cases were above 1.0. We used the Computer-aided thermography.

In this study we observed two abdominal areas to evaluate the abdominal temperature. And the mean temperature of Square A in dysmenorrhea group was 35.22±1.33 °C and in control group was 36.01±0.74 °C.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-922, 1998

2.6.3-4 Oct. 31 SAT 9:15 - 9:30 Rm207/208 910
Infrared Imaging in Minimally Invasive Surgery

Marcucci L, Freeman J, Quinn T, Hopmeier M, Milner R, Friedberg J, Buyske J, University of Pennsylvania, USA Email:marcucc2@mail.med.upenn.edu

Minimally invasive surgery is now in widespread use in both adult and pediatric patients. Lack of tactile feedback, limited range of motion of the surgical instruments and inability to discern anatomic features and pathological conditions remain major drawbacks to this modality. Infrared technology can assist the surgeon by delineating structures and improving visualization on a real-time basis.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-926, 1998

2.6.3-5 Oct. 31 SAT 9:30 - 9:45 Rm207/208 737
Prerequisites of Dynamic Area Telethermometry (DAT)

Anbar M, Milescu L, Sch. of Medicine, Sunyab and Biomedical Science, USA Email:amara@adelphia.net

Use of DAT (Dynamic Area Telethermometry), a highly useful biomedical technique based on infrared imaging, presents a set technical prerequisites that are not critical for static infrared imaging. These include the use of highly sensitive focal plane array (FPA) infrared cameras that allow acquisition of >=30 sequential images/sec, the use of infrared detectors sensitive in the >8 μm range (e.g. HgCdTe or Ga/As QWIP) to avoid artifacts due to skin reflectivity, the effective thermostated cooling of the detectors to minimize noise and avoid modulation of sensitivity, and the use of software that facilitates effective extraction of clinically useful data from hundreds of selected subareas on 1024 or more sequential thermal images.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-928, 1998

2.6.3-6 Oct. 31 SAT 9:45 - 10:00 Rm207/208 281
Simulation and Experiment on Biological Tissue for Near Infra-Red (NIR) Photon Migration in A Multi-Layered Model

Ding HS, Su C, Lin F, Wang F, Ying JP, Tsinghau University, China Email:dhs-dea@mail.tsinghua.edu.cn

To study the phenomenon of infrared photon migration in a multi-layered tissue is very useful in biomedicine such as noninvasive optical monitoring of physiological parameters and the optimal dosimetry of the photodynamic therapy. Multi-layered models for the research of NIR light propagation in biological tissue are established using Monte-Carlo simu-lation. Photon tracking and parameter correcting methods across the boundary of tissue layers with mismatched optical properties are provided. Experimental results on animal tissue are presented, and a close relationship has been found between the actual measurement and the simulation.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-932, 1998

2.6.4 Infrared Imaging II

Session Chair: Michael Anbar,Sch. of Medicine, Sunyab and Biomedical Science,USA

Session Co-Chair: J. Harding,St. Woolos Hosptial,UK

2.6.4-1 Nov. 1 SUN 22:30 - 22:45 Rm207/208 551
Imaging of Skin Thermal Properties by Changing Ambient Radiation Temperature - An Electrical Control System for Stepwise Change in Ambient Radiation Temperature

Hassan M, Kimura Y, Asai A, Shimase A, Fukuoka M, Togawa T, Tokyo Medical and Dental University, Japan Email:hassan@inst.i-mde.tmd.ac.jp

A practical measurement system has been developed for creating an image of skin thermal properties using a stepwise change in ambient radiation temperature. By introducing a capacitor discharge circuit, more rapid stepwise change in ambient temperature was achieved, at a rate 30% faster than a mechanical system [3]. Numerous experiments were performed using our present system on the facial skin of the cheek. The repeatability of thermal properties of the same subject suggests that the present system is reliable for practical use.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-936, 1998

2.6.4-2 Nov. 1 SUN 22:45 - 23:00 Rm207/208 686
Development of A Skin Temperature Measuring System for Non-Contact Stress Evaluation

Kataoka H, Kano H, Yoshida H, Saijo A, Yasuda M, Osumi M, Sanyo Electric Co. Ltd., Japan Email:M33KATAOKA@hr155.a1.co.jp

Skin temperature is an effective indicator for objectively evaluating human sensations, because it is controlled by sympathetic nerve activity which reflects the course of information processing in the brain. In this paper, we show a method to evaluate stress from skin temperature and an equipment which continuously measures skin temperature of an subject working in front of a computer terminal.

An experiment is performed to investigate a relationship between stressfull task and the skin temperature. The experiment shows that there is a high correlation among stress, skin temperatures on nose and forehead. From this experiment, a regression equation is derived which computes the intensity of stress from skin temperatures on nose and forehead.

A non-contact skin temperature measuring system is developed based on knowledge obtained in the experiment. The system comprised of an infrared camera, color camera, image processing unit and work station. The features are the abilities to track nose and forehead positions of an subject doing computer operation automatically and to evaluate the stress continuously.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-940, 1998

2.6.4-3 Nov. 1 SUN 23:00 - 23:15 Rm207/208 301

Consistent Digital Color Image Acquisition of the Skin

Vander Haeghen Y, Naeyaert JM, Lemahieu I, University Gent, Belgium Email:Yves. VanderHaeghen@rug.ac.be

We propose a simple, quick and practical color calibration procedure that results in a precise (reproducible), albeit not very accurate (close to values obtained with a reference device), color description in a standard device-dependent color space (sRGB). The system consists of a 3-chip CCD camera, a continuous ring-light, frame grabber and PC. The calibration procedure involves building a profile of the acquisition system based on 24 color targets with known characteristics. This profile is easily checked before a set of image acquisitions and remains valid for a long period. The acquired images are transformed from the device-dependent RGB camera space to the gamma corrected sRGB (or ITU-R BT.709) space and are readily displayable on a CRT-based monitor. Moreover, sRGB tristimulus values are readily transformed to the CIE L*a*b* space, allowing perceptual color differences (Delta E*ab) to be computed. Although the accuracy of the proposed procedure is not very high (Delta E*ab>10 for some of the color targets), the precision or reproducibility is quite good. The short-term precision based on 20 consecutive measurements of a white patch is <Delta E*ab >= 0.04, with Delta E*ab < 0.1. The medium-term precision, based on 10 measurements of the 24 color patches made during different warm-up cycles of the acquisition system under one profile is <Delta E*ab> =0.34 with Delta E*ab < 1.2. Long-term or inter-profile precision is of the same order, even when the color temperature of the light source is changed between profiles.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-944, 1998

2.6.4-4 Nov. 1 SUN 23:15 - 23:30 Rm207/208 930

Development of A New Infrared Imaging System: An Infrared Image Superimposed on the Visible Image

Fujimasa I, Kouno A, Nakazawa H, National Graduate Institue for Policy Studies, Japan Email:goopky@grips.ac.jp

The infrared imaging, especially far infrared thermography, is a typical non-invasive measurement method in clinical medicine. However, the applications have been used mainly in clinical testing laboratory, and not used in outpatient clinics or operation rooms with on-line mode. The reason exist on the difficulty of the positional identification from the infrared image. We have been testing combination of visible image and infrared image. Recently, compact non-cool infrared cameras become commercially available. Using the camera, a new infrared imaging system by which we can observe superimposed infrared image on its visible image have been developed. The image from an object is separated infrared and visible light using Inconel metal coated mirror and guides to an infrared camera (Thermal Vision LAIRD 3A) and a video camera (Handyscope) separately. The measured images are mixed digitally with an image mixer (Digital Video Mixer MX-1) and display an overlapped image on a monitor. The developed system was tested on an animal experiment and was evaluated its feasibility for clinical usage.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-950, 1998

2.6.4-5 Nov. 1 SUN 23:30 - 23:45 Rm207/208 708

Temperature Measurement in the External Auditory Meatus by An IR Optical Fiber

Mizote M, Matsuzaki H, Teikyo Heisei University, Japan Email:mizote@cn.thu.ac.jp

A system to measure temperature in the external auditory meatus (EAM) using an IR optical fiber was developed. Radiant heat in EAM was transmitted through an IR optical fiber to the focal area of IR-camera with expansive lens and temperature per area was calculated by the radiant heat. On the basis of difference between room temperature and an object temperature, temperature of the object was calibrated at the room temperature between 19 and 28 °C. Because radiant heat is calibrated to body temperature using the room temperature sensed in the IR-camera. The temperature is relative temperature change, but it is measured easily because the room temperature change is included in the calibration. Temperature in EAM could be measured every 0.1s, while subjects pulled a back muscle dynamometer as powerfully and quickly as possible. The temperature in EAM raised just before exercise. It is suggested that the temperature change shows brain activity like EEG and EMG in physiological exercises.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-953, 1998

2.6.4-6 Nov. 1 SUN 23:45 - 0:00 Rm207/208 1008

Development of An Image Processing Software for Medical Thermogram Analysis Using A Commercially Available Image Processing System

Fujimasa I, Nakazawa H, Miyasaka E, National Graduate Institue for Policy Studies, Japan Email:goophy@grips.ac.jp

The medical far infrared (FIR) imaging system has recently been modified more sensitive, rapid and cheap and recently image format for processing on a personal computer and output format from integrated circuit of a FIR sensor have gradually been standardized. The objectives of the report is to develop an application software to analyze clinical FIR images, which is obtainable in market. Therefore, we intended to develop new programs which are written as macro programs on a commercially available image processing software and by which any digital image data with known data format become applicable to the standard to the standard FIR image analysis system in medicine. NIH Image was introduced as an image processing software. Sequence of calls or routines for other medical oriented image processing were written with macro codes in Macintosh computers. We aimed to obtain the same image processing software. Sequence of calls or routines for other medical oriented image processing were written with macro codes in Macintosh computers. We aimed to obtain the same image processing functions which had been developed for medical computer thermography system [3]. Every source FIR image was converted temperature images (thermograms). Marking on same temperature region (isotherm), making temperature profiles (line scan) and temperature histogram of region of interest (ROI), drawing temporal temperature difference image (dT thermogram), comparing the temperature difference of two ROI (asymmetry detection thermogram), and displaying thermography index thermogram (TI thermogram) have been developed.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-956, 1998

2.6.5 Biomedical Image Analysis

2.6.5-1 Oct. 31 SAT 14:30 - 16:00 Rm201 422

Detection of Patient Movement for Video EEG Monitoring

Chang YD, Lee DG, Ryoo SY, Lee DS, Hanyang University, Korea Email:kiwi@shira.hanyang.ac.kr

We propose a method to monitor automatically the motion of an epileptic during video EEG monitoring. The method consists of two procedures. First, it segments a head image into objects which are head, mouth and eyes. Second, the spatial local optimization method is employed for the estimation of optical flow, which quantifies the motion. And then, we obtain the averaged optical flow and set a threshold level to detect the motion event of the objects, respectively. Finally, when the averaged optical flow is more than the threshold level, the motion event of each objects are decided. In the results, we show that the optical flow represents the detail motion of a patient.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-959, 1998

2.6.5-2 Oct. 31 SAT 14:30 - 16:00 Rm201 335

Wavelet-Based Enhancement of Human Chromosome Images

Wu Q, Castleman KR, Perceptive Scientific Instruments, Inc, USA Email:qwu@persci.com

Human chromosomes contain important information for cytogenetics analysis. Cytogeneticists compare their patient's chromosome images against the prototype human chromosome band patterns. Computer enhancement of chromosome bands in the images facilitate visualization and karyotyping. Currently available systems employing conventional convolution filtering are similar to photomicroscopy in their ability to support the detection of band pattern alterations. Improvement in visualization quality and capability of effective band enhancement for detail analysis would significantly increase the cost-effectiveness of these instruments.

In this paper we describe a new technique developed for human chromosome image enhancement, based on the cubic-spline wavelet transform and multiresolution image analysis. Under this approach, chromosome band pattern features can be characterized compactly in the transform domain by a multiresolution image representation. Enhancement of these features can be achieved with designed flexibility in scale, orientation, location, and degree of enhancement, by analyzing and selectively processing the transform coefficients. This technique promises improved image enhancement means to assist the evaluation of chromosome abnormalities in clinical samples. Experimental results are presented to exemplify the feasibility of the approach.

Proc. of the 20th Annual International Conf. of IEEE-EMBS, Vol. 20, II-963, 1998

2.6.5-3 Oct. 31 SAT 14:30 - 16:00 Rm201 181

Autofluorescence Spectorscopy to Identify Normal and Cancerous Colorectal Tissues

Wang CY, Lin JK, Chiang HHK, National Yang-Ming University, Taiwan, China Email:crab@bme.ym.edu.tw

The light induced autofluorescence spectroscopy was performed to identify normal and cancerous colorectal tissues. In this study, a total of 20 normal and 20 cancerous tissues were obtained from patients receiving oncological surgery of colon and rectum. We measured and analyzed the autofluorescence spectra at 280 to 400 nm excitations in 10 nm increments to search for the optimal excitation wavelength. For each sample, we calculated the "two-peak ratio" value to distinguish between normal and cancerous tissues at different excitation wavelengths. By using the Student's t-test, we found that there are statistically significant differences in the "two-peak ratio" of the autofluorescence spectra between normal and cancerous tissues at 300, 320, 330 and 340 nm excitations ($p<0.001$). Furthermore, by applying the Receiver Operating Characteristic (ROC) curves, the 330 nm excitation, which yielded 85% sensitivity, 90% specificity, and 89% positive predictive value when appropriate threshold was

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Track 11.6: Infrared Imagimg

Session 11.6.1: Digital Infrared Imaging I *Saturday Oct-16-1999, 16:00- 18:00* (Regency V, Slide)

1) *Diagnosis of Deep Vein Thrombosis with NIR Spectroscopy*, Scott F.D. Jr.; Kang K.A.; Williams G.M.

The goal of this study is to utilize near-infrared spectroscopy as a non-invasive, inexpensive method of diagnosing deep vein thrombosis. The probe contains two light sources and two filter detectors that record deoxyhemoglobin and oxyhemoglobin changes by measuring reflected light intensity of wavelengths 760 and 850 nm. These changes and the sum of these (blood volume) changes, are measured over a time period in which the subject undergoes a series of light exercises. The test protocol is designed to determine the tissues's blood volume capacity, rate of filling and efficiency to promote one-directional venous flow. The subject pool consists of Johns Hopkins Hospital Vascular Surgery patients diagnosed with leg deep vein thrombosis with normal subjects as the control. Abnormal venous systems have distinct characteristics: high blood volume; quick rate of filling; and, the inability to decrease the blood volume during the contraction of the muscle.

2) *The Role of Infrared Thermal Imaging (ITI) in Management of Neuropathic Pain*, Hooshang H.; Masood H.; Phillips E.M.

The value of Infrared thermal imaging (ITI) is limited to evaluation of neurovascular dysfunction. It provides useful diagnostic and therapeutic information in the management of neuropathic pain[1]. Key Words: Infrared thermal imaging , neuropathic pain, ITI in pain management.

3) *Development of a Human Thermal Model and Its Applications for Thermographic Diagnosis*, Kakuta N.; Yokoyama S.; Mabuchi K.

A mathematical model has been developed for the numerical analysis of thermal conditions within the human body. The model is based on a numerical calculation of bio-heat equation and a mathematical model of a thermoregulation system. The internal temperatures, heat fluxes, and blood temperatures of all segments are calculated simultaneously. We try to apply the model to clinical diagnosis by using thermography images. This paper describes the fundamental analysis of the calculated results and the experimental results. The calculated results compared rather well with the experimental results in some thermal environmental conditions.

4) *Infrared Imaging in the Long-term Follow Up of Osteomyelitis Complicating Diabetic Foot Ulceration*, Harding J.R.; Banerjee D.; Wertheim D.F.; Williams R.J.; Melhuish J.M.; Harding K.G.

Diabetic foot ulcers are susceptible to secondary infection; when this occurs, there is risk of spread of the infection to adjacent bone, resulting in the serious complication of osteomyelitis, which may be clinically silent in this group of patients. Prompt, aggressive treatment with appropriate antibiotics is indicated to prevent even more serious complications ranging from loss of the foot or limb to death. A previous study has shown that infrared imaging is useful in identifying those patients with diabetic foot ulceration at particular risk of developing clinically silent osteomyelitis. This long-term follow-up study has used infrared imaging to trace the progress of these patients.

5) *Uncooled 640 x 480 IR Camera for Medical Applications*, White T.; Leary A.

Uncooled digital infrared focal plane arrays have added a new imaging capability for medical applications. Temperature sensitivity and spatial resolution previously limited to expensive space and military systems applications are now affordable for medical applications and as easy to use as a video camera. This paper presents the results to date obtained moving toward a 640 X 480 camera to be evaluated for medical applications.

6) *Atherosclerotic Plaque Temperature Measurements with Infrared Fiber Optic Imaging*, Guo B.; Casscells W.; Bearman G.; McNatt J.; Naghevi M.; Malik B.A.; Gul K.; Willerson J.T.

Rupture of atherosclerotic plaques-the main cause of heart attack and strokes-is not predictable. Fatal plaques are found at autopsies to be associated with active inflammatory cells. Classically, inflammation sites have been characterized by heat, swelling, red color and pain (calor, tumor, rubor and dolor). We have demonstrated in vitro that heat accurately locates the dangerous plaques that are significantly warmer then those plaques without inflammation. In order to develop a non-surgical method of locating these plaques, an infrared fiber optic imaging methodology has been developed in our laboratory to evaluate the causes and effect of heat in atherosclerotic plaques. The temperature heterogeneity of atherosclerotic plaques developed in the arterial of the experimental animal models is under study with the new device. The preliminary experimental results from the animal model are encouraging. The potential of using this new technology in diagnostic evaluation of the vulnerable atherosclerotic plaques is considerable.

7) *System Dynamics Analysis of Dynamic Far Infrared Images in Medicine*, Fujimasa I.; Miyasaka E.; Nakazawa H.; Matsuura H.

The objectives of the report are to develop a simulation model for thermal convection near the skin surface, to make an application software for analyzing dynamic far infrared images, and to establish a new analysis system of dynamic thermography for clinical medicine. Firstly, dynamic thermal images were taken by a FIR camera (Thermal Vision LAIRD 3A, Nikon) and stored in a digital-videotape. Secondary, the images were sent to a Macintosh computer using DVCap software (Canon) and converted to a QT movie. Thirdly, the QT movie was processed with a simulation model in the NIH image system. In order to analyze the dynamic images a thermal convection model was developed using system dynamics software (STELLA, High Performance Systems Inc.). After thermal and mechanical stresses were applied to a hu-

man body, the dynamic changes of skin temperature were observed by the system. Blood flow rate distribution of cutaneous tissue and sympathetic control factors were detected using the system.

Session 11.6.2: Digital Infrared Imaging II *Saturday Oct-16-1999, 10:00- 12:00* (Grand Hall East, Poster)

1) *Advanced Thermal, Visual and Radiological Image Processing for Clinical Diagnostics*, Wiecek B; Zwolenik S; Jung A.; Zuber J.

This paper presents multi-channel system with for advanced image processing for thermal, visual and radiological images. Novel methods mainly based on statistical data processing and 3D reconstruction are implemented. The system was successfully used for pneumonia treatment.

2) *Numerical Analysis of CP-MCT and Image Restoration by the Computed Projection*, Miyakawa M.; Orikasa K.; Ishii N.; Bertero M.; Boccacci P.

A method for FD-TD based field analysis of the chirp radar-type microwave tomography (CP-MCT) has been developed. By taking the computed projection of a thin cylinder to be the point spread function (PSF) of CP-MCT, image restoration has been attempted and successful results have been obtained.

3) *Fan Beam Microwave Scanner for High Speed Temperature Imaging*, Miyakawa M.; Itoh H.; Takabayashi M.; Bertero M.; Boccacci P.

For high-speed imaging of the chirp radar-type microwave computed tomography (CP-MCT), a fan beam-type microwave scanner which works at 1~2 GHz has been developed. By introducing the electronic scan into the microwave scanner with the receiving antenna consisted of 43 small dipole antennas, data acquisition is completed within 200 seconds.

4) *Improvement of Thermal Properties Imaging System of Skin by Changing Ambient Radiation Temperature in Stepwise Fashion*, Saito H.; Kimura Y.; Moinudin H.M.D.; Otsuka K..; Shimase A.; Ocada S.; Tsuchiya T.; Togawa T.

This paper proposes a system to make images on skin thermal properties such as emissivity, thermal inertia and emissivity-corrected thermography. The properties are estimated by measurement of the time course of temperature during changing ambient temperature in stepwise fashion. Discharge from huge capacitances to electrical heater which is controlled by their temperature can heat the ambient radiation from 20 to 40 c. The time course of temperature on skin surface is almost linear against square root of time, which fits the theory. We can conclude that the system is practically applicable.

5) *Design and Testing of a Near-Infrared Computed Tomography Device for Breast Tumor Characterization*, Paulsen K.D.; Pogue B.W.; McBride T.O.; Osterberg U.L.

The design of a frequency-domain near-infrared scanning device is considered in order to determine how the source-detector geometry affects the resulting reconstruction of the tissue images. The measurements are processed by a finite element-based algorithm which reconstructs the interior image map of the absorption and scattering coefficients. This reconstruction is achieved by matching the light fluence measurements to calculated values based upon the assumption that light diffuses in tissue, and is predicted by the diffusion equation. An initial series of computer simulations have been used to evaluate the source- detector geometry, and predict how the measurement geometry affects the reconstruction accuracy and image quality. A physical device has been realized, using the optimal design, and is currently in a clinical trial to characterize the optical properties of breast tissues and tumors in vivo. The device uses 16 source and 16 detector locations alternating in a circular array, which can be attached to the breast tissue during a patient exam. Initial phantom and tissue studies indicate that quantitatively accurate images of the absorption coefficient can be obtained at multiple near infrared wavelengths.

6) *Quantitative Retrieval of Temperature of Breast Cancers by Microwave Radiometric Imaging (MWI)*, Bocquet B.; Mouty S.; Ringot R.; Leroy Y.; Rocourt N.; Robert Y.; Devos P.; Beuscart R.

We have developed a fast MicroWave radiometric Imaging system (MWI) which realizes thermal images with a good spatial resolution. We are making at the present time, a large clinical evaluation for the breast tumor characterization in an early stage. A Received Operating Curve (ROC) statistical analyze in an intermediate stage of 60 patients, gives a sensibility and a specificity up to 80%. We show here that this technique could complete the non-invasive radiological outcome in terms of benign-malignant characterization. Moreover, the use of an inverse problem technique in the spatial frequency domain gives a quantitative measurement of cancer temperature. It is now possible to consider in a new application such as the followed of the temperature during a chimiotherapy treatment.

Session 11.6.3: Digital Infrared Imaging III *Friday Oct-15-1999, 13:30- 15:30* (Chicago EF, Slide)

1) *Structural and Functional Tissue Analysis under Skin Using Near Infrared Spectral Imaging*, Fujimasa I.; Nakasawa H.

The infrared imaging will be a typical non-invasive measurement method in clinical medicine. However, pathophysiological meaning of infrared imaging has not been analyzed schematically. We have developed an infrared imaging system, which can detect spectroscopic images from near infrared images to far infrared thermography. Near infrared images are taken by a cooled charge-couple-device (cooled CCD) applying active right source such as a halogen light and laser diodes in reflecting and transparent mode. Middle infrared images are measured by an infrared camera, which can detect short wave length less than 3.0 microns. Far infrared images are taken by a dynamic thermographic instrument to measure radiated ray. Using projected infrared ray of 880 nm, vascular network in subcutaneous tissue has been observed in transparent and reflective mode. Using infrared ray of 760 nm and 800 nm, blood volume and oxygenation image of subcu-

taneous tissue has been obtained in dynamic mode. A near infrared image of subcutaneous tissue combined with a thermal image of skin surface which was simultaneously taken by an image overlapping method [1], and was analyzed pathophysiological function of cutaneous tissue.

2) *Objective Detection of Breast Cancer by Dynamic Area Telethermometry (DAT)*, Anbar M.; Brown C.; Milescu L.

Classical thermology involves visual localization of abnormalities in the spatial distribution of temperature over human skin. Dynamic area telethermometry (DAT), on the other hand, which extracts diagnostic information from temporal changes in skin temperature,1 yields quantitative information on the detailed structure of skin temperature modulation including the underlying frequencies and their corresponding relative amplitudes. Significantly abnormal values of these parameters, which quantitatively describe the dynamics of skin perfusion, can be of great diagnostic importance. DAT is typical of the new trend in thermology to focus on dynamic physiological rather than on anatomical thermal manifestations of disease.2 DAT focuses on rapid periodic changes in skin temperature, caused by cardiogenic pulsatile hemodynamics as well as by neuronal regulation of blood flow in the vasculature.3 Quantitative analysis of these changes can reveal pathology in the cardiovascular or neuronal systems, as well as pathologies that affect the function of the latter. It has been suggested that cancerous lesions attenuate the neuronal control of perfusion in their surroundings by extravascular production of nitric oxide.4 This hypothesis was confirmed when breast carcinoma was shown to produce nitric oxide.2 DAT can be used to quantify these local effects of neoplastic disease and thus detect and localize breast cancer in an objective manner. DAT involves accumulation of thousands of consecutive infrared images in the > 8 (range over relatively short periods (>30 sec), achievable with modern QWIP cameras.3 Fast Fourier transformation (FFT) is used to obtain the relative contributions of individual discrete frequencies to the overall periodic modulation. The spatial distribution of abnormalities in thermoregulatory amplitudes can be visually displayed or quantitatively analyzed. It has been found that cancerous breasts are associated with significantly lower relative amplitudes in the affected areas. Moreover, the frequencies at which minimal amplitudes occur differ significantly between cancerous and non-cancerous breasts. The attenuated amplitudes and the sequence of frequencies that exhibit the most significant attenuation have been used as objective diagnostic parameters, without the help of imaging display. Using this methodology, we were able to demonstrate high significant differences between cancerous breasts and breasts with no known pathology or breasts with benign abnormalities (see Figure 1). AMT in Figure 1 is a parameter derived from a set of frequencies selected for their content of strongly attenuated subareas; XRM = X-ray mammography. In this diagnostic methodology, visual presentation is used solely to localize cancerous lesions after their presence was objectively determined without visualization. In brief, although breast cancer detection by DAT involves infrared imaging as input, its output is a quantitative diagnostic figure of merit that can be treated like any other quantitative diagnostic parameter. 1. M. Anbar: Quantitative Dynamic Telethermometry in Medical Diagnosis and Management. CRC Press Inc. Boca Raton, Fl, 1994. 2. M. Anbar: Clinical Thermal Imaging Today - Shifting from phenomenological thermography to pathophysiologically based thermal imaging. IEEE Engineering in Medicine and Biology Magazine 17 (4): 25-33, 1998. 3. M. Anbar, M. W. Grenn, M. T. Marino, L. Milescu and K. Zamani: Fast dynamic area telethermometry (DAT) of the human forearm with a Ga/As quantum well infrared focal plane array camera. Eur J Thermology 7:105-118, 1997. 4. M. Anbar: Hyperthermia of the cancerous breast - analysis of mechanism. Cancer Letters 84:23-29, 1994.

3) *Comparison of Mammography and Breast Infrared Imaging: Sensitivity, Specificity, False Negatives, False Positives, Positive Predictive Value and Negative Predictive Value*, Head J.F.; Lipari C.A.; Elliott R.L.

Breast infrared imaging (IRI) for detection of breast cancer has been unfairly maligned as having unacceptably high false positive and false negative rates. IRI actually has statistical performance characteristics that are similar to mammography. The false positive rate of 14% is about twice as high as mammography but surgical intervention is not possible (no increase in invasive procedures). Also, the false negatives of IRI do not hinder the detection of breast cancer by physical exam, mammography and ultrasound. Finally, the ability of IRI to predict who will develop breast cancer is not appreciated and IRI results should be used to select patients for prevention trials.

4) *Diagnosis of Nerve Entrapment Syndromes by Thermal Imaging*, Ammer K.

Thermal images of 154 hands were studied to show that patients suffering from thoracic outlet syndrome or carpal tunnel syndrome can be differentiated from healthy subjects by the occurence of a thermal asymmetry between the index and the little finger. A temperature difference between these fingers higher than 0,5 >C was regarded as a pathological finding. With respect to clinical, neurographic and thermographic criteria, hands were allocated into four groups: healthy controls, carpal tunnel syndrome, thoracic outlet syndrome and the combination of carpal tunnel with thoracic outlet syndrome. A discriminant analysis of grouping with respect to the temperature difference between index and little finger, found correct classification in 44,8 % of cases. After transfer of the combined syndrome to the thoracic outlet group, the number of correct classifications increased to 63,3%. The calculation for sensitivity and specificity of pathological temperature differences for the diagnosis of thoracic outlet syndrome yielded values of 71,60 and 42,9 %. The determination of the temperature distribution on the hand seems to be a valuable test for the detection of patients with thoracic outlet syndrome.

5) *Visible and Infrared Hyperspectral Visualization of Normal and Ischemic Tissue*, Zuzak K.J.; Schaeberle M.D.; Levin I.W.; Lewis N.E.; Freeman J.; McNeil J.D.; Cancio L.C.

We have developed a new in-vivo spectroscopic imaging system (IVIS) for real-time biomedical applications. IVIS

visualization produces images that are acquired non-invasively during clinical procedures. This paper describes data collected from tissue to determine the efficacy of this type of hyperspectral imaging modality for measuring changes in the spatial distribution of regional tissue oxygenation during vascular occlusion and reperfusion.

6) *Blood Flow Imaging Algorithm for Infrared Thermographic Systems*, Kondo K.; Ishigaki H.; Konishi Y.; Mabuchi K.

The most important information obtained by thermographic tests is not the absolute value of the temperature itself, but rather its distribution on space or time variables. In this paper, we propose an effective imaging method for infrared thermographic systems. Especially, it is applied to the change detection of blood flow in the infrared images. This purpose is achieved by using image-subtraction technique and spatio-temporal filter for motion enhancement. Through simulation result, it is shown the change of blood flow is detected clearly.

7) *A Focal Plane Array System for Clinical Infrared Imaging*, Ring E.F.J.; Minchinton M.A.B.; Elvins D.M.

Thermal infrared imaging (IR) in medicine has been dependent on single element detectors with mechanical scanning systems for four decades. Modern IR systems now offer high speed, high resolution. This paper reports a study made during an upgrade from a cooled single element Agema 782M imager to a new uncooled focal plane array Thermovision (Flir systems Inc.). The results show spatial resolution to be higher with the new Thermovision, resolving skin vasculature. The autocalibration of this camera can produce some temperature measurement variability.

Track 11.7: Other Imaging Techniques

Session 11.7.1: Other Imaging Techniques I *Friday Oct-15-1999, 10:00- 12:00* (Grand Hall East, Poster)

1) *Ultrasound Active Areas in the Auditory Cortex Measured by 122-Channel Whole-Head Neuromagnetometer*, Tonoike M.; Hosoi H.; Imaizumi S.; Sakaguchi T.; Nakagawa S.; Yamaguchi M.; Nishimura T.

This paper presents a study on the ultrasonic hearing aids and perception tests for both normal hearing subjects and profoundly deaf people and their active location of estimated signal sources in the brain. In these experiments auditory activities by bone-conducted ultrasonic stimuli were measured by magnetoencephalography (MEG) using a 122ch whole-head neuromagnetometer. Both subjects of the normal hearing and the profoundly deaf people could perceived the ultrasound stimuli, however their active center in the brain of the latter people was found in a different region (superior temporal area) from the former subjects. These results suggest the reorganization of the auditory central nervous system in human.

2) *Forward Problem Solution of EMSIs Using BEM with Isoparametric Cubic Elements*, Gencer N.G.; Tanzer I.O.

Numerical solution of the potential and magnetic fields for a given electrical source distribution in the human brain is an essential part of the electro-magnetic source imaging. In this study, Boundary Element Method (BEM) is used that employs 10-noded cubic triangular elements. The results are given in comparison with the solutions obtained using linear and quadratic elements. The relative difference measure obtained for the numerical models that use different element types show the superiority of quadratic and cubic element types.

3) *Monte Carlo Optimization of 4D Smoothing Methods for Gated Myocardial Perfusion SPECT*, Lalush D.S.; Segars W.P.; Tsui B.M.W.

In this paper, we develop a technique for optimizing space-time smoothing methods proposed for gated myocardial perfusion SPECT. Gated SPECT synchronizes image acquisition with an ECG signal so that a time loop of 3D SPECT images is acquired. The optimization technique employs a realistic spline-based beating heart phantom. We simulate noise-free SPECT data from the phantom including all principal physical degrading effects, and then we simulate an ensemble of noisy datasets. Each member of the ensemble is processed using the candidate reconstruction method, varying the smoothing parameters to optimize bias and variance of a quantitative measure representing the task to be performed with the study. The method is demonstrated on the optimization of smoothing parameters for left ventricular volume estimation. We conclude that Monte Carlo simulation using realistic models of motion is essential in predicting and optimizing performance of 4D reconstruction methods.

4) *Sub-band Denoising Technique for High Noise PET Image Analysis*, Lin H.D.; Lin K.P.; Yu C.L.; Wu L.C.; Liu R.S.

To improve the high noise problem for PET image is important work that the quality of the PET image and the diagnosis accuracy is effected by the noise.For this reason, a novel sub-band denoising technique is provided in this paper. The method is based on the subband transformation and the statistical method. By using the technique the noise can be inhibited effectively.

Session 11.7.2: Other Imaging Techniques II *Friday Oct-15-1999, 16:00- 18:00* (Chicago CD, Slide)

1) *Discrete Coil Induced Current Impedance Tomography*, Eyuboglu M.; Koksal A.; Demirbilek M.

A discrete coil induced current imaging system is proposed. The solution methodology of the forward problem of this system is explained. For concentric inhomogeneity problem, optimum coil currents that maximize the distinguishability are obtained.

2) *Magnetic Resonance Conductivity Imaging*, Birgul O.; Eyuboglu B.M.; Ider Y.Z.

A new imaging modality combining electrical impedance tomography (EIT) and magnetic resonance imag-ing (MRI), by utilizing both the voltage measurements from EIT and magnetic field measurements from MRI, is proposed and

Medical Physics

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June 2000 Volume 27, Number 6

Track 01: Diagnostic Physics, Medical Imaging, and Image Processing

Chair: Robert G. Gould, Sc.D., San Francisco, CA
Co-Chair: Dr. Richard M. Leahy, Los Angeles, CA

MO - A305	Nuclear Physics Refresher Course
MO - B305	PET/Nuclear Imaging
MO - B307	CT Instrumentation
MO - E305	Nuclear Imaging
MO - E307	Mammography Computer Aided Diagnosis
MO - FXH	Poster Session: I Diagnostic Physics, Medical Imaging, and Image Processing - Nuclear Imaging/PET
MO - G305	Cardiovascular Imaging
MO - G307	CAD Image Analysis
TU - A307	Mammography Refresher Course
TU - CXH	Poster Session: I Diagnostic Physics, Medical Imaging, and Image Processing - Optical Imaging
TU - E303	Optical Imaging
TU - E305	T/CT Reconstruction
TU - E307	Digital Mammography
TU - FXH	Poster Session: I Diagnostic Physics, Medical Imaging, and Image Processing - Mammography
TU - FXH	Poster Session: II Diagnostic Physics, Medical Imaging, and Image Processing - Infrared Imaging in Medicine
TU - G303	Infrared Imaging in Medicine
TU - G305	Image Fusion
TU - G307	Mammography
WE - A307	Imaging Science Refresher Course
WE - B303	Minisymposium: Infrared Imaging I
WE - B305	3D
WE - B307	Digital Detectors/CR
WE - C303	Minisymposium: Infrared Imaging II
WE - CXH	Poster Session: I Diagnostic Physics, Medical Imaging, and Image Processing - CAD/PACS/Absorptiometry/Cardiovascular
WE - E303	fMRI/MRS
WE - E305	CAD Feature Extraction 1
WE - FXH	Poster Session: I Diagnostic Physics, Medical Imaging, and Image Processing - MR/CT/US
TH - A305	Ultrasound Refresher Course
TH - B303	Image Guided Surgery
TH - B305	Ultrasound 1
TH - CXH	Poster Session: I Diagnostic Physics, Medical Imaging, and Image Processing - Projection Imaging/Quality Assurance/Ultrasound
TH - E303	Impedance Imaging
TH - E305	Ultrasound 2
TH - E307	Bone Mineral/Absorptiometry
TH - FXH	Poster Session: I Diagnostic Physics, Medical Imaging, and Image Processing - Impedance and EEG
TH - G301	PACS/Compression
TH - G303	EEG
TH - G305	Image Registration
TH - G307	MRA/MR Instrumentation
TH - G324	Art and Physics
FR - A324	MRI Refresher Course
FR - B305	CAD Feature Extraction 2

Tuesday, July 25, 2000 (continued)

2:30 pm **TU-EBR-04** Multimodality Image Correlation Quality Assurance Anthropomorphic Phantom - S. Mutic *, W. Bosch, R. Drzymala, K. Chao, D. Low, J. Lewis, P. Cutler

2:40 pm **TU-EBR-05** Compensating Filters for IMRT I: Material Characterization and Process Verification - T. Grigereit *, B. Nelms, J. Dempsey, J. Garcia-Ramirez, D. Low, J. Purdy

2:50 pm **TU-EBR-06** A Quality Assurance Phantom for IMRT Dose Verification - C. Ma *, S. Jiang, T. Pawlicki, Y. Chen, J. Li, J. Deng, M. Lee, E. Mok, A. Boyer

3:00 pm **TU-EBR-07** Commissioning and Testing of a Commercial Intensity Modulated Treatment Planning System - F. Kuchnir *, C. Reft, L. Johnson, J. Kung, C. Pelizzari, J. Roeske

3:10 pm **TU-EBR-08** Monitor Unit Calculations as Part of Beam Commissioning for a Radiation Treatment Planning System - G. Starkschall *, R. Steadham, Jr, N. Wells, L. O'Neill, L. Miller, I. Rosen

3:20 pm **TU-EBR-09** Testing Beta Version of Cadplan / Helios at MGH - P. Zygmanski *, J. Kung, H. Kooy, J. Beatty, P. Biggs, K. Doppke, M. Bues, G. Chen

3:30 pm **TU-EBR-10** A New Multipurpose Quality Assurance Phantom for Clinical Tomotherapy - J. Smilowitz *, J. Balog, H. Keller, G. Olivera, L. DeWerd, T. Mackie

Poster Session

3:40 pm - 4:50 pm

-Room: Exhibit Hall

TU-FXH Poster Session: I Diagnostic Physics, Medical Imaging, and Image Processing - Mammography

TU-FXH-01 Combining Data From Different Algorithms to Segment the Skin-Air Interface in Mammograms - M. Masek *, Y. Attikiouzel, C. deSilva, M. Masek

TU-FXH-02 New Method to Analysis of Results Obtained by Computer Aided Diagnosis in Digital Radiography - S. Rodrigues *, A. Frère

TU-FXH-03 Performance of a Processing Scheme for Clustered Microcalcifications Detection with Different Images Database - H. Schiabel *, F. Nunes, M. Escarpinati, R. Benatti

TU-FXH-04 Model-Based Mammographic Image Segmentation - G. McGarry *, M. Deriche

TU-FXH-05 Simulation of Mammographic Structures to Benefit the Computer Aided-Diagnosis - H. Oliveira *, H. Oliveira, A. Frère, P. Azevedo Marques

TU-FXH-06 Computerized Segmentation of Lesions in Breast Sonography - K. Horsch *, M. Giger, L. Venta, M. Kupinski, C. Vyborny

TU-FXH-07 Investigation of Clustered Microcalcifications Features for An Automated Classifier as Part of a Mammography CAD Scheme - A. Patrocínio *, H. Schiabel, R. Benatti, C. Goes, F. Nunes

TU-FXH-08 Computerized Classification of Mass Lesions On Special View Mammography - Z. Huo *, M. Giger

TU-FXH-09 Evaluation of Contrast Enhancement by Digital Equalization in Digital Mammography - W. Huda *, Y. Jin, A. Laine

TU-FXH-10 Out of Plane Structure Removal in Mammographic Tomosynthesis Imaging Using a Coupled Source and Detector in a C-Arm Configuration - J. Rakowski *, M. Dennis

Tuesday, July 25, 2000 (continued)

TU-FXH-11 Contrast Enhancement Procedure for Digital Images of Dense Breasts by Using Tissues Attenuation Coefficients - F. Nunes *, H. Schiabel, F. Nunes

TU-FXH-12 Phantoms Used for Evaluation of Full Field Digital Mammography Systems - R. Kaczmarek *, J. Thomas, K. Chakrabarti

TU-FXH-13 An Evaluation of Tomosynthetic Linear and Non-Linear Reconstruction Techniques for Digital Mammography - S. Suryanarayanan *, A. Karellas, S. Vedantham, S. Glick, C. D'orsi, R. Webber

TU-FXH-14 The Localization and Visualization of Breast Lesion in Digitized Mammogram - B. Cho, J. Woo, W. Mun, I. Kim, S. Kim *

TU-FXH-15 Mammographic X-Ray Spectra Evaluation for Dose/image Quality Optimization - C. Gomes *, H. Schelin, E. Yoshimura, P. Costa, J. Tilly, F. Barros

TU-FXH-16 Evaluation of Breast Composition for Radiation Absorbed Dose in Mammography - S. Goto *, Y. Azuma, T. Maruyama, Y. Takeda, M. Azuma

TU-FXH-17 Algorithms of Correction of the Heel Effect in the Mammographics Images - M. Nascimento *, M. Marques

TU-FXH-18 X-Ray Scattering From Breast Phantoms and Human Breast Tissues - M. Poletti, O. Gonçalves *, I. Mazzaro

TU-FXH-19 Evaluation of Resolution Contrast, Scatter/Primary Ratio and Grid Performance with Breast Phantoms and Human Breast Tissue - M. Poletti *, O. Goncalves, I. Mazzaro

TU-FXH-20 Evaluation of Mammographic Image Quality and Dose in Mexican Hospitals - C. Ruiz-Trejo, N. Montes, M. Rodriguez, M. Brandan *, M. Verdejo-Silva, A. Flores, L. Madero-Preciado, M. Guevara

TU-FXH-21 Quality Control of Biopsy Stereotactic Equipment - C. Almeida, A. Bacelar, R. Lykawka, F. Bittelbrum, A. Furtado, F. dos Santos *

TU-FXH-22 A Mammographic Accreditation Program for Venezuela - A. Diaz *, A. Díaz

TU-FXH-23 Testing Mammography Film Processors: The Sensitometer and the Control Film - O. Suleiman *, D. Spelic, R. Slayton, M. Hilohi, R. Gray

TU-FXH-24 How the Quality Control Program Can Help The Clinical Detectability of Findings in Mammograms - R. Medeiros *, F. Rodrigues Alves, A. Ferreira, S. Elias, F. Fingerman, C. Kemp

TU-FXH-25 Phase Contrast Mammography with Synchrotron Radiation: A Digital Approach - F. Arfelli, V. Bonvicini, G. Cantatore, E. Castelli, L. Dalla Palma, R. Longo, R. Menk, A. Olivo *, S. Pani, P. Poropat, M. Prest, A. Rashevsky, L. Rigon, G. Tromba, A. Vacchi, E. Vallazza

-Room: Exhibit Hall

TU-FXH Poster Session: II Diagnostic Physics, Medical Imaging, and Image Processing - Infrared Imaging in Medicine

Chairs: Jonathan Head, Elliott Mastology Center, Baton Rouge, LA and Kunihiko Mabuchi, The University of Tokyo, Tokyo, Tokyo, Japan

TU-FXH-26 Diagnosis of Breast Cancer with Infrared Dynamic Area Telethermometry (DAT) - M. Anbar *, L. Milescu, C. Brown, C. Carty, A. Naumov, E. Bachman, K. AlDulaimy, C. Geronimo, T. Button

Tuesday, July 25, 2000 (continued)

TU-FXH-27 Standardization of Thermographic Breast Cancer Detection ? Role of Qualitative Findings and Quantitative Findings ? - H. Usuki *, H. Maeta, T. Maeba, H. Wakabayashi, F. Goda, Y. Karasawa, A. Misawa, S. Mori, K. Okano

TU-FXH-28 Tau Image: A Diagnostic Imaging Technique Based On the Dynamic Digital Telethermography - A. Merla *, L. Di Donato, G. Romani

TU-FXH-29 Detecting Breast Cancer From Infrared Images by Asymmetry Analysis - H. Qi *, W. Snyder, J. Head, R. Elliott

TU-FXH-30 Imaging of Thermal Inertia to Visualize Reactive Hyperemia in the Forearm Skin After Arterial Occlusion - M. Hassan *

-Room: Exhibit Hall

TU-FXH Poster Session: III Radiation Therapy Physics - Stereotactic/Quality Assurance

TU-FXH-31 Extraction of Biological Parameters for AVM Stereotactic Radiotherapy Treatment - P. Mavroidis *, K. Theodorou, D. Lefkopoulos, M. Schlienger, B. Lind, C. Kappas

TU-FXH-32 Tumor Position Displacement as a Function of Patient Orientation for Stereotactic Frames - M. Schell *, A. Perec, D. Rosenzweig, C. Maurer, Jr., A. Soni, T. Barry, A. Matloubieh, G. Beranek

TU-FXH-33 OMEGA Monte Carlo Test of the Gamma Knife Dosimetry - K. Ayyangar, R. Mooij, P. Nizin *

TU-FXH-34 Three Dimensional Dose Verification of a Stereotactic Irradiation Using a Novel Polymer Gel/x-Ray CT Dosimetry Technique - C. Audet *, M. Hilts, A. Jirasek, C. Duzenli

TU-FXH-35 Dosimetry Measurements of Radiosurgery Fields with a PTW Miniature Ion Chamber - X. Ren *

TU-FXH-36 A Technique For Reducing The Effect Of Isocenter Precession For Stereotactic Therapy Using A Micro-Multileaf Collimator - S. Toner *, J. Shih, S. Chiu-Tsao, P. Gliedman, L. Harrison

TU-FXH-37 The Comparison of Treatment Planning Between Conventional Conformal Radiotherapy and Stereotactic Conformal Radiotherapy Using Phantom - K. Kim *, J. Jang, J. Kim, J. Kim, M. Cho

TU-FXH-38 Optimization of 3D Gamma Knife Treatment Planning - P. Zhang *, D. Dean, A. Metzger, C. Sibata

TU-FXH-39 Feasibility of Using A 0.5 Cm MLC for Radiosurgery Purpose - J. Ting *, S. Ghavidel, G. Yang, L. Davis

TU-FXH-40 Measurment of Scatter Correction Factor for Stereotactic Irradiation - H. Ohtani *, T. Irifune, T. Fujisaki, T. Inada, M. Tsuda, H. Saitoh, M. Fukushi, T. Katoh

TU-FXH-41 Treatment Planning for Stereotactic Radiotherapy Using Large-Field Beams - B. Cho *, S. Han, Y. Ko, D. Oh, H. Bae

TU-FXH-42 Stereotactic Radiotherapy in Pediatrics: Radionics' XPlan Verses XKnife - S. Jaywant *, N. Laperriere

TU-FXH-43 Extra-Cranial Radiosurgery Using a Commercial Inverse Planning System - F. Newman *, W. Dzingle, K. Stuhr, S. Meyer, S. McCourt, A. Eagle

TU-FXH-44 An Algorithm for Stereotactic Localization with CT/MR Images - J. Dai *, Y. Zhu, H. Qu, Y. Hu

Tuesday, July 25, 2000 (continued)

TU-FXH-45 Comparison of On-Site and Off-Site Evaluations of Dosimetry Data - J. BenComo *, D. Followill, S. Cho, P. Balter, R. Tailor, J. Lowenstein, N. Hernandez, W. Hanson

TU-FXH-46 Thirty Years of the IAEA/WHO TLD Postal Dose Quality Audits for Radiotherapy - J. Izewska *, P. Bera, P. Andreo, A. Meghzifene

TU-FXH-47 Design of a Heterogeneous Thorax Phantom for Remote Verification of Three-Dimensional Conformal Radiotherapy - C. Cherry *, D. Followill, W. Hanson

TU-FXH-48 Dissemination and Maintenance of Standards at Therapy Level at the National Metrology Laboratory for Ionizing Radiation, Brazil - L. Rodrigues *, M. de Araujo, C. da Silva, D. do Nascimento, L. Baptista

TU-FXH-49 Analysis of Daily Beam Output Data for Teletherapy Machines - Y. Watanabe *

TU-FXH-50 A Regional Quality Assurance Programme for the Physical Aspects of Radiotherapy - R. Alfonso-Laguardia *, F. Aguirre, M. Brunetto, F. Gutt, P. Andreo

TU-FXH-51 Evaluation of Two Water-Equivalent Phantom Materials for Output Calibration of Photon and Electron Beams - L. Liu *, S. Prasad, D. Bassano

TU-FXH-52 A Quality Assurance Device for the Accuracy of the Isocenters of Teletherapy and Simulation Machines - B. Arjomandy *, M. Altschuler

TU-FXH-53 Clinical Evaluation of a New Comprehensive Image Based Quality Assurance System for Medical Linear Accelerators - R. Wlodarczyk *, K. Welsh, L. Reinstein

TU-FXH-54 Maintenance and Electrical Calibration of Dosimetric Equipment Used in Radiotherapy in Brazil - P. Becker *, M. Péres, H. Nette

TU-FXH-55 Experimentally Assessed Achievable Accuracy in Radiotherapy Dosimetry - D. Thwaites *, M. Allahverdi

TU-FXH-56 A Quality Assurance Program for Radiotherapy Centers in Korea - G. Kim *, H. Oh, W. Pyun, H. Lee

TU-FXH-57 Use of A Kalman Filter in Clinical Radiation Therapy Calibration - S. Zhou *

TU-FXH-58 Construction and Dosimetry Characterization of a Breast Phantom as a Quality Assurance Test for Clinical Radiotherapy Treatment Planning Systems - O. Laiton *, M. Plazas, F. Diaz, O. Mattos, G. Murcia, A. Mejia

TU-FXH-59 Comparison of Monitor Units Calculated From Treatment Planning Systems and From TPR Tables - S. Naidu, I. Rosenberg *, D. Mockridge

TU-FXH-60 Acceptance Testing and Commissioning of A Ximatron Radiotherapy Simulator - P. Ravindran *, B. Subramaniam, R. Singh, D. Raj

-Room: Exhibit Hall

TU-FXH Poster Session: IV Radiation Safety and Protection - Safety in Diagnostic and Nuclear Medicine

TU-FXH-61 Calibration of TL Detectors for Skin Entrance Dose Postal Quality Control in Dental Radiology - L. Rosa *, M. Maréchal, J. Feital, S. Girão

TU-FXH-62 Study of Work Conditions at the Radiological Health Services in the State of São Paulo - S. Cecatti *, C. Gronchi, L. Furnari, R. Gomes

TU-FXH-63 Radiological Protection in Dentistry in the Capital of Brazil - C. Dias *, R. Ferreira, R. Corrêa, I. Nícoli

Tuesday, July 25, 2000 (continued)

5:20 pm TU-G206-02 A Telematic Based Education System for Life Long Learning Students of Movement Analysis - T. Leo, S. Fioretti *, M. Maurizi, F. Verdini, M. Marini

5:40 pm TU-G206-03 Locomotion Systems Study in Biomedical Engineering Curriculum - V. Medved *

-Room: 301

TU-G301 Track 09: Neural Engineering

Chair: Dominique Durand, Case Western Reserve University, Cleveland, OH

5:00 pm TU-G301-01 A Study of Carpal Tunnel Injury Following Electrical Trauma - M. Morse *

5:10 pm TU-G301-02 The Bergman's Insuline-Glucose Regulation Model: DNN-State Observer - A. Garcia, A. Cabrera *, A. Poznyak, T. Poznyak

5:20 pm TU-G301-03 Synaptic Noise Improves Detection of Subthreshold Signals in Hippocampal CA1 Cells - W. Stacey *, D. Durand

5:30 pm TU-G301-04 Modification of Epileptiform Bursting Using Chaos Control - M. Slutzky *, D. Mogul

5:40 pm TU-G301-05 Frequency-Dependent Examination of Homosynaptic Long-Term Depression in the Freely Moving Rat - J. Blaise *, J. Bronzino

5:50 pm TU-G301-06 Algorithms for Real-Time Prediction in Neural Systems - G. Stanley *

-Room: 303

TU-G303 Track 01: Infrared Imaging in Medicine

Chairs: Jasper Lupo, Office of the Under Secretary of Defense (Science & Technology) Pentagon, Washington, DC and William Sander, U.S. Army Research Office, Research Triangle Park, NC

5:00 pm TU-G303-01 Evaluation of Autonomic Nervous Function by Image-Processing of High-Speed Dynamic Far-Infrared Thermal Images - K. Kondo *, K. Mabuchi, N. Kakuta, A. Hoshikawa, A. Kouno, S. Haeno, H. Ishigaki

5:10 pm TU-G303-02 Infra Red Thermal Imaging in Peripheral Vascular Diseases - F. Ring *, R. Harding

5:20 pm TU-G303-03 A Newly Developed Thermal Coronary Angiography System - I. Fujimasa *, H. Nakazawa, S. Kawada

5:30 pm TU-G303-04 Visualization and Detection of Ischemia Using Visible Spectroscopic and Infrared Thermal Imaging Techniques - K. Zuzak *, M. Schaeberle, E. Lewis, I. Levin

5:40 pm TU-G303-05 Data-Processing Method for Standardization of Thermographic Diagnosis - J. Wakamiya *, K. Mabuchi, I. Fujimasa, S. Nakagawa, H. Miyake, K. Arimura, M. Osame, A. Igata, Y. Takizawa

5:50 pm TU-G303-06 A NIR Optical Imaging System with Diffuse Photons - Y. Zhang *, J. Bai, N. Chen, D. Liu

-Room: 305

TU-G305 Track 01: Image Fusion

Chair: Samuel Armato, The University of Chicago, Chicago, IL

5:00 pm TU-G305-01 Data Fusion and Stochastic Optimization: Application to Esophagus Outer Wall Detection On Ultrasound Images - R. Debon *, B. Solaiman, M. Robaszkiewicz, C. Roux

5:10 pm TU-G305-02 Multimodal 3-D Image Registration of MRI-SPECT Volume Images - G. Tzanakos *, A. Abche, E. Micheli-Tzanakou, T. Stahl, X. Wan, T. Yudd

Tuesday, July 25, 2000 (continued)

5:20 pm TU-G305-03 Optimal Localization and Image Fusion for DSA/CT/MRI Using Leksell Frame - D. Shin *, T. Suh, H. Lee, B. Choe, K. Shinn

5:30 pm TU-G305-04 Implementation of Mutual Information Based Multi-Modality Registration - S. Luo *, X. Li

5:40 pm TU-G305-05 Quantification of Brain Tissue Volumes Using MR/MR Fusion - V. Barra *, J. Boire

5:50 pm TU-G305-06 High-Speed Interactive Multimodality Image Fusion Tool-Kit - Y. Yan *, A. Boyer, K. Montgomery

-Room: 307

TU-G307 Track 01: Mammography

Chair: Libby Brateman, University of Florida, Gainesville, FL

5:00 pm TU-G307-01 Experimental and Simulation Results of Two-Dimensional Prototype Anti-Scatter Grids for Mammography - C. Tang *, T. Fewell, R. Jennings, R. Fahrig, D. Jaffray, M. Yaffe

5:10 pm TU-G307-02 An Apparatus for Positron Emission Mammography-Guided Breast Biopsy - R. Raylman *, S. Majewski, R. Wojcik, A. Weisenberger, B. Kross, V. Popov, J. Schreiman, H. Bishop

5:20 pm TU-G307-03 Appropriate Phantom for AEC Compensation Testing in Mammography - J. Nosil *, J. MacDonald, K. Situ

5:30 pm TU-G307-04 Evaluation of An Electronic Mammography AEC Density Tracking Test Tool - D. Gauntt *, F. Daffin, G. Barnes

5:40 pm TU-G307-05 Mammography Calibration Standards: The MQSA Sensitometer Calibration Facility - O. Suleiman, D. Spelic *, R. Slayton, S. Belella, M. West

5:50 pm TU-G307-06 Relationship Between Phantom Failure and Radiation Dose in Mammographic Accreditation - A. Haus *, M. Yaffe, S. Feig, R. Hendrick, P. Butler, P. Wilcox-Buchalla, S. Bansal

-Room: 309

TU-G309 Track 02: Stereotactic/Gamma Knife 1

Chairs: Robert Drzymala, Mallinckrodt Inst. Radiology, St. Louis, MO and Vernon Smith, University of California San Francisco, California

5:00 pm TU-G309-01 Feasibility of Real-Time Tracking of a Moving Treatment Site During Image-Guided Radiosurgery - M. Murphy *, J. Adler, Q. Le, V. Mehta, H. Roberts, M. Bodduluri, G. Glosser

5:10 pm TU-G309-02 Beam's Eye View Geometric Optimization of Isotropic Beam Bouquets for Stereotactic Radiosurgery and Radiotherapy Treatment Planning - T. Wagner *, F. Bova, S. Meeks, W. Friedman, J. Buatti

5:20 pm TU-G309-03 Vicenza Hospital Experience with the Photon Radiosurgery System - P. Francescon, C. Cavedon *, F. Colombo

5:30 pm TU-G309-04 Evaluation of a New Relocatable Head Fixation System - A. Olch *, R. Lavey

5:40 pm TU-G309-05 A Feasibility Study Using a Stereo-Optical Camera System to Verify Gamma Knife Treatment Specifications - R. Drzymala *, C. Guo, J. Sohn, K. Rich, J. Simpson, T. Wasserman

5:50 pm TU-G309-06 Comparison of 80% Vs 50% Radiosurgery Dose Prescription Based On Biological Modelling - V. Smith *, L. Verhey, P. Petti

Wednesday, July 26, 2000 (continued)

8:50 am **WE-Ba326-02 Phthalocyanine 4 (Pc 4) Concentration Dosimetry for In Vivo Photodynamic Therapy Using a New Non-Invasive, Site-Specific Spectroscopic Device** - V. Colussi *, D. Feyes, J. Mourant, H. Mukhtar, T. Kinsella, I. Bigio, C. Sibata

9:10 am **WE-Ba326-03 Expert System for Transcutaneous Drug Delivery -A Recent Approach** - R. Subbaraman *, S. Prabha, D. Gopalakrishnan, V. Rajamani

9:30 am **WE-Ba326-04 Synthesis and Research of Composition Ingredients of a Rehability Prophylactical Operation Remedy** - E. Avrorin, M. Cherkashin, E. Kurbatova, V. Pokrovsky, A. Tsvetokhin, A. Xenofontov *, J. Regens

9:50 am **WE-Ba326-05 Control and Optimization of Electroporation-Mediated Drug and Gene Delivery** - P. Canatella, M. Black, C. McKenna, E. Ghartey-Tagoe, J. Karr, J. Petros, M. Prausnitz *

-Room: 327

WE-Ba327 Track 07: Cardiac Functional Imaging

Chairs: Randy Setser, Barnes-Jewish Hospital at Washington University Medical Center and Samuel Wickline, Washington University School of Medicine, St. Louis, MO

8:30 am **WE-Ba327-01 Molecular Imaging of Angiogenesis with Targeted Contrast Agents** - G. Lanza, C. Hall, M. Scott, R. Fuhrhop, C. Lorenz, S. Fischer, S. Flacke, X. Yu, P. Gaffney, D. Abendschein, S. Wickline, S. Wickline

8:50 am **WE-Ba327-02 Can Intravascular Ultrasound Characterize the Arterial Wall and Guide Interventional Procedures** - M. O'Donnell *

9:10 am **WE-Ba327-03 Advances in Cardiovascular Magnetic Resonance Imaging** - C. Lorenz *, S. Fischer, R. Setser, S. Flacke, J. Chia, S. Wickline

9:30 am **WE-Ba327-04 Bi-Ventricular Mechanical Activation Time Mapping** - C. Ozturk *, E. MCVeigh

9:40 am **WE-Ba327-05 Automatic Initialization for a Snakes-Based Cardiac Contour Extraction** - V. Medina *, R. Valdés, O. Yañez-Suárez, M. Garza-Jinich, J. Lerallut

9:50 am **WE-Ba327-06 Image Based Stochastic Mechanics Framework for Non-Invasive Recovery of Myocardial Material Properties** - P. Shi *, A. Sins

10:00 am **WE-Ba327-07 Imaging of Micromyocardial Metabolic Activity and Microvascularblood Flow Distribution** - Y. Ogasawara *, T. Kajita, T. Matsumoto, H. Tachibana, H. Nakamoto, S. Mochizuki, C. Tokuda, F. Kajiya

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9:00 am - 10:20 am

-Room: 201

WE-B201 Track 04: Round Table: Towards Global Information Infrastructure

Chairs: Ilias Iakovidis, European Commission, DG XIII, Brussels, Belgium and Pekka Karp, European Commission, DG XIII, Brussels, Belgium

9:00 am **WE-B201-01 Emerging Trends in Information Technology** - S. Laxminarayan

9:10 am **WE-B201-02 RETRANSPLANT : REgional and International Integrated Telemedicine Network for Medical Assistance in End Stage Diseases and Organ TRANSPLANT (HC 4028 & IN 4028 European Commission DGXIII)** - S. Vari, G. Brugal, F. Godo

Wednesday, July 26, 2000 (continued)

9:30 am **WE-B201-03 Intranet Health Clinic: An International Collaboration for Transfer of Clinical Data** - Y. Skalkidis *, A. Stavropoulou, S. Edworthy

9:50 am **WE-B201-04 Need for Global Collaboration On Ultrasound Technology** - S. Stergiopoulos

-Room: 204

WE-B204 Track 23: Bioelectric Mapping and Inverse Problems

Chairs: Bin He, University of Illinois at Chicago, Chicago, IL and Ramesh Gulrajani, Universite de Montreal, Montreal, Quebec, Canada

9:00 am **WE-B204-01 Laplacian Transformation of the EEG Signal for a Reliable Quantification of Cortex Interrelationships** - A. Bianchi *, S. Cerutti

9:10 am **WE-B204-02 Regularization Parameter Selection Criteria in the Inverse Problem of Electrocardiography** - R. Gulrajani *, P. Johnston

9:20 am **WE-B204-03 Three-Dimensional Source Imaging of Cardiac Electrical Activity** - B. He *, D. Wu

9:30 am **WE-B204-04 Integration of High Resolution EEG and FMR for the Analysis of the Cortical Rhythms Related to Voluntary Movements** - F. Babiloni *, F. Carducci, C. Del Gratta, F. Cincotti, M. Palomba, G. Romani, P. Rossini, C. Babiloni

9:40 am **WE-B204-05 Space-Time Treatment of Inverse Bioelectric Field Problems** - F. Greensite *

9:50 am **WE-B204-06 Non-Invasive Imaging of Pericardial Spectra** - D. Beetner *, R. Arthur

-Room: 303

WE-B303 Track 01: Mini-Symposium: Infrared Imaging I

Chairs: Nicholas Diakides, Advanced Concepts Analysis, Inc., Falls Church, VA and Iwao Fujimasa, GRIPS, Tokyo, Japan

9:00 am **WE-B303-01 Selective Applications of IR Imaging in Medicine** - K. Ammer, B. Jones *, F. Ring, B. Jones

9:20 am **WE-B303-02 Dynamic Area Telethermometry (DAT)** - M. Anbar *

9:40 am **WE-B303-03 The Physical Basis of Thermal Imaging** - R. Balcerak *, J. Lupo

-Room: 305

WE-B305 Track 01: 3D

Chair: Donald Peck, Henry Ford Health System, Detroit, MI

9:00 am **WE-B305-01 Realistic Three-Dimensional Model of the Central Airways Using Healthy Volunteer CT Images** - V. Sauret *, J. Fleming, A. Bailey

9:10 am **WE-B305-02 Vision-Based Three Dimensional Reconstruction by Integrating N Images** - Y. Cheng *, C. Dewey

9:20 am **WE-B305-03 Self Similar Interpolation of 3D Medical Data** - P. Asvestas, G. Matsopoulos *, K. Nikita

9:30 am **WE-B305-04 Determination of Detectable Lesion Volume Change Using MR Images and Image Analysis** - D. Cody *, D. Peck, E. Monsell, E. Spickler, L. Marian, G. Divine

9:40 am **WE-B305-05 Quantitative Analysis of Left Ventricle Shape and Motion, Using a 3D Dynamic Model: Deformable Superquadrics** - V. Torrealba, A. Bosnjak *, M. Acuña, B. Solaiman, G. Montilla, C. Roux

Wednesday, July 26, 2000 (continued)

WE-CXH-137 Preventive Maintenance in Surgical Centers - E. Berns *, R. Garcia

WE-CXH-138 Movable Neonatal Intensive Care Unit: A Technology Adaptation by Clinical Engineering - K. Ferreira *, J. Martins, R. Garcia

WE-CXH-139 Compulsory Certificate of Medical Electrical Equipment in Brazil: Evolution From 1997 to 2000 - S. da Silva *, E. de Oliveira, M. Bottaro, V. Viana, P. Costa

WE-CXH-140 The Establishment of Clinical Engineering in Venezuelan Hospitals - L. Lara, R. Mijares, R. Silva *

-Room: Exhibit Hall

WE-CXH Poster Session: VIII Physiological Modeling - Modeling

WE-CXH-141 Identification of a Hammerstein Model of the Stretch Reflex EMG Using Separable Least Squares - D. Westwick, R. Kearney *

WE-CXH-142 Alterations of Glucose Metabolism Indexes in Hypertension - S. Natalucci *, M. Boemi, P. Fumelli, I. Testa, D. Fumelli, R. Burattini

WE-CXH-143 Comparison of Minimal Model Based Estimates of Insulin Sensitivity and Glucose Effectiveness in SHR and WKY Rats - S. Natalucci *, P. Ruggeri, V. Picchio, C. Cogo, R. Burattini

WE-CXH-144 Simulation of Swimming Pattern in the Lamprey Using Network of Single Compartment Neuron Models - P. Kudela *, P. Franaszczuk

WE-CXH-145 A Model of the Hoffman Reflex - T. Ward *

WE-CXH-146 An Artificial Neural Network Model for Generating Periodic Signals by Synchronizing External Stimuli - K. Fujimoto, G. Cottenceau, M. Akutagawa *, H. Nagashino, Y. Kinouchi

WE-CXH-147 The Limits of Heart-Model-Based Computerized ECG Diagnosis - S. Szilágyi *

WE-CXH-148 Modeling the Anatomical Changes During Cardiac Cycle in the Model of the Thorax as a Volume Conductor - H. Puurtinen *, J. Hyttinen, M. Kankimäki, J. Malmivuo

WE-CXH-149 Variations of Parameters of Bioimpedance During Upper Limb Movement - T. Nakamura *, Y. Yamamoto

WE-CXH-150 Estimation of Impedance Changes Inside the Human Head During Neuronal Depolarisation: Implications for Electrical Impedance Imaging of the Brain - A. Liston *, R. Bayford, K. Boone, D. Holder

WE-CXH-151 A Model for Continuously Mutant HIV-1 - H. Ortega *, M. Martín-Landrove

WE-CXH-152 Modeling and Realizing Biological Mechanisms On FPGAs Chip - N. Botros *

WE-CXH-153 Interaction of Hemodynamics and Gas Exchange: A Computer Simulation - A. Qiu *, J. Bai

Refreshment Break — Exhibit Hall

10:20 am - 11:30 am — Lounge Areas

Wednesday, July 26, 2000 (continued)

Scientific Session

10:20 am - 11:30 am

-Room: 303

WE-C303 Track 01: Mini-Symposium: Infrared Imaging II

Chairs: Francis Ring, Royal National Hospital for Rheumatic Diseases, Bath, United Kingdom and Raymond Balcerak, Defense Advanced Research Projects Agency, Arlington, VA

10:20 am WE-C303-01 Body Surface Temperature: Manifestation of Complex Anatomy and Physiology of Cutaneous Vasculature - G. Brengelmann *

10:40 am WE-C303-02 Infrared Imaging in the Detection and Evaluation of Tumor Angiogenesis - W. Li *, J. Head

11:00 am WE-C303-03 Theraml-Coronary-Angiography (TCA) for Intraoperative Evaluation of Graft Patency in Coronary Artery Bypass Surgery - V. Falk *, H. Kitzinger, T. Walther, A. Diegeler, T. Rauch, F. Mohr

-Room: 309

WE-C309 Track 12: Error in Medicine Symposium (Part II of III)

Chairs: Geoffrey Ibbott, Dept. of Radiation Medicine, University of Kentucky, Lexington, KY and Jay Goldberg, Marquette University/ Medical College of Wisconsin, Milwaukee, WI

10:20 am WE-C309-01 Medical Errors, Medical Journals, and the 'the Stochastic Art' - D. Herbert *

10:50 am WE-C309-02 Improving Patient Safety: A Research Agenda for Medical Physicists and Biomedical Engineers - W. Hendee *

Plenary Session

11:40 am - 12:40 pm

-Room: Ballroom

WE-DBR Ethics in Biotechnology and Medicine

Chairs: Joseph Bronzino, Trinity College, Hartford, CT and Bruce Thomadsen, University of Wisconsin, Madison, WI

11:40 am WE-DBR-01 Medical Technology in the 21st Century: The Ethical Isssues - George J. Annas, Boston University School of Public Health, Boston, MA

Scientific Session

2:00 pm - 3:40 pm

-Room: 201

WE-E201 Track 04: Mini-Symposium: Wireless Telemedicine in the 21st Century I

Chairs: Robert Istepanian, Brunel University, Uxbridge, United Kingdom and Sotiris Pavlopoulos, Athens, Greece

2:00 pm WE-E201-01 Next Generation of Integrated Mobile and Internet Telemedicine Systems - R. Istepanian, S. Laxminarayan, Z. Derezinski

2:20 pm WE-E201-02 All Weather Emergency Telemedicine - Current and Future Trends - S. Pavlopoulos

2:40 pm WE-E201-03 Remote Sensing of Vital Signs with Telecommunications Signals - V. Lubecke *, O. Boric-Lubecke, G. Atwater, P. Ong, P. Gammel, R. Yan, J. Lin

3:00 pm WE-E201-04 Wireless Interface for Monitored Patients in Coronary Care Units - J. Presedo, D. Castro, J. Vila, M. Fernandez-Delgado, S. Fraga, M. Lama, S. Barro